

ANTISENSE OLIGONUCLEOTIDE MODULATION OF STAT3 EXPRESSION

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FIELD OF THE INVENTION

This invention relates to compositions and methods
15 for modulating expression of the human STAT3 gene, which
encodes a naturally present DNA-binding protein involved in
signal transduction and transcriptional activation, and is
implicated in disease. This invention is also directed to
methods for inhibiting STAT3-mediated signal transduction
20 and transcriptional activation; these methods can be used
diagnostically or therapeutically. Furthermore, this
invention is directed to treatment of conditions associated
with expression of the human STAT3 gene.

25 BACKGROUND OF THE INVENTION

The STAT (signal transducers and activators of
transcription) family of proteins are DNA-binding proteins
that play a dual role in signal transduction and activation
of transcription. Presently, there are six distinct
30 members of the STAT family (STAT1, STAT2, STAT3, STAT4,
STAT5, and STAT6) and several isoforms (STAT1 , STAT1 ,
STAT3 and STAT3). The activities of the STATs are
modulated by various cytokines and mitogenic stimuli.
Binding of a cytokine to its receptor results in the
35 activation of Janus protein tyrosine kinases (JAKs)
associated with these receptors. This in turn,

phosphorylates STAT, resulting in translocation to the nucleus and transcriptional activation of STAT responsive genes. Phosphorylation on a specific tyrosine residue on the STATs results in their activation, resulting in the
5 formation of homodimers and/or heterodimers of STAT which bind to specific gene promoter sequences. Events mediated by cytokines through STAT activation include cell proliferation and differentiation and prevention of apoptosis.

10 The specificity of STAT activation is due to specific cytokines, i.e. each STAT is responsive to a small number of specific cytokines. Other non-cytokine signaling molecules, such as growth factors, have also been found to activate STATs. Binding of these factors to a cell surface
15 receptor associated with protein tyrosine kinase also results in phosphorylation of STAT.

STAT3 (also acute phase response factor (APRF)), in particular, has been found to be responsive to interleukin-6 (IL-6) as well as epidermal growth factor (EGF) (Darnell, Jr., J.E., et al., *Science*, 1994, 264, 1415-1421). In
20 addition, STAT3 has been found to have an important role in signal transduction by interferons (Yang, C.-H., et al., *Proc. Natl. Acad. Sci. USA*, 1998, 95, 5568-5572). Evidence exists suggesting that STAT3 may be regulated by the MAPK
25 pathway. ERK2 induces serine phosphorylation and also associates with STAT3 (Jain, N., et al., *Oncogene*, 1998, 17, 3157-3167).

STAT3 is expressed in most cell types (Zhong, Z., et al., *Proc. Natl. Acad. Sci. USA*, 1994, 91, 4806-4810). It
30 induces the expression of genes involved in response to tissue injury and inflammation. STAT3 has also been shown to prevent apoptosis through the expression of bcl-2 (Fukada, T., et al., *Immunity*, 1996, 5, 449-460).

Aberrant expression of or constitutive expression of STAT3 is associated with a number of disease processes. STAT3 has been shown to be involved in cell transformation.

It is constitutively activated in v-src-transformed cells (Yu, C.-L., et al., *Science*, 1995, 269, 81-83). Constitutively active STAT3 also induces STAT3 mediated gene expression and is required for cell transformation by src (Turkson, J., et al., *Mol. Cell. Biol.*, 1998, 18, 2545-2552). STAT3 is also constitutively active in Human T cell lymphotropic virus I (HTLV-I) transformed cells (Migone, T.-S. et al., *Science*, 1995, 269, 79-83).

Constitutive activation and/or overexpression of STAT3 appears to be involved in several forms of cancer, including myeloma, breast carcinomas, prostate cancer, brain tumors, head and neck carcinomas, melanoma, leukemias and lymphomas, particularly chronic myelogenous leukemia and multiple myeloma. Niu et al., *Cancer Res.*, 1999, 59, 5059-5063. Breast cancer cell lines that overexpress EGFR constitutively express phosphorylated STAT3 (Sartor, C.I., et al., *Cancer Res.*, 1997, 57, 978-987; Garcia, R., et al., *Cell Growth and Differentiation*, 1997, 8, 1267-1276). Activated STAT3 levels were also found to be elevated in low grade glioblastomas and medulloblastomas (Cattaneo, E., et al., *Anticancer Res.*, 1998, 18, 2381-2387).

Cells derived from both rat and human prostate cancers have been shown to have constitutively activated STAT3, with STAT3 activation being correlated with malignant potential. Expression of a dominant-negative STAT3 was found to significantly inhibit the growth of human prostate cells. Ni et al., *Cancer Res.*, 2000, 60, 1225-1228.

STAT3 has also been found to be constitutively activated in some acute leukemias (Gouilleux-Gruart, V., et al., *Leuk. Lymphoma*, 1997, 28, 83-88) and T cell lymphoma (Yu, C.-L., et al., *J. Immunol.*, 1997, 159, 5206-5210). Interestingly, STAT3 has been found to be constitutively phosphorylated on a serine residue in chronic lymphocytic leukemia (Frank, D. A., et al., *J. Clin. Invest.*, 1997,

100, 3140-3148). In addition, antisense oligonucleotides to STAT3 have been shown to promote apoptosis in non small cell lung cancer cells (Song et al., *Oncogene* 22:4150, 2003) and prostate cancer cells (Mora et al., *Cancer Res.* 5 62:6659, 2002).

STAT3 has been found to be constitutively active in myeloma tumor cells, both in culture and in bone marrow mononuclear cells from patients with multiple myeloma. These cells are resistant to Fas-mediated apoptosis and 10 express high levels of Bcl-xL. STAT3 signaling was shown to be essential for survival of myeloma tumor cells by conferring resistance to apoptosis. Thus STAT3 is a potential target for therapeutic intervention in multiple myeloma and other cancers with activated STAT3 signaling. 15 There is a distinct medical need for novel therapies for chemoresistant myeloma. Velcade was approved in May 2003 with an 188 evaluable patient pivotal trial based on tumor shrinkage, not survival. 28% showed a partial response. The data is currently under FDA review.

20 Catlett-Falcone, R., et al., *Immunity*, 1999, 10, 105-115. A gene therapy approach in a syngeneic mouse tumor model system has been used to inhibit activated STAT3 in vivo using a dominant-negative STAT3 variant. This inhibition of activated STAT3 signaling was found to 25 suppress B16 melanoma tumor growth and induce apoptosis of B16 tumor cells in vivo. Interestingly, the number of apoptotic cells (95%) exceeded the number of transfected cells, indicating a possible antitumor "bystander effect" in which an inflammatory response (tumor infiltration by 30 acute and chronic inflammatory cells) may participate in killing of residual tumor cells. Niu et al., *Cancer Res.*, 1999, 59, 5059-5063. Constitutively activated STAT3 is also associated with chronic myelogenous leukemia.

STAT3 may also play a role in inflammatory diseases 35 including rheumatoid arthritis. Activated STAT3 has been found in the synovial fluid of rheumatoid arthritis

patients (Sengupta, T.K., et al., *J. Exp. Med.*, 1995, 181, 1015-1025) and cells from inflamed joints (Wang, F., et al., *J. Exp. Med.*, 1995, 182, 1825-1831).

Multiple forms of STAT3 exist, generated by
5 alternative splicing. STAT3 is a short form of STAT3
(also, STAT3) that differs predominately by the absence of
55 amino acid residues at the C-terminus. This domain
contains the transactivation domain, and thus, STAT3 may
act as a negative regulator of STAT3 function (Caldenhoven,
10 E., et al., *J. Biol. Chem.*, 1996, 271, 13221-13227).
STAT3 has been found to be more stable and have greater
DNA-binding activity than STAT3 , while STAT3 is more
transcriptionally active.

There are currently several approaches for inhibiting
15 STAT3 expression. US Patent Nos. 5,719,042 and 5,844,082
to Akira, S. and Kishimoto, T. disclose the use of
inhibitors of APRF, including antibodies, antisense nucleic
acids and ribozymes for the treatment of IL-6 associated
diseases, such as inflammatory diseases, leukemia, and
20 cancer. Schreiber, R.D., et al., in US Patent Nos.
5,731,155; 5,582,999; and 5,463,023, disclose methods of
inhibiting transcriptional activation using short peptides
that bind p91. Darnell, J.E., et al., in US Patent No.
5,716,622, disclose peptides containing the DNA binding
25 domain of STATs, chimeric proteins containing the DNA
binding domain, and antibodies to STATs for inhibiting STAT
transcriptional activation.

The use of an antisense oligonucleotide targeted to
the translation start region of human STAT3 has been
30 disclosed (Grandis, J. R., et al., *J. Clin. Invest.*, 1998,
102, 1385-1392). In this report, a phosphorothioate
oligodeoxynucleotide complementary to the translation start
region of STAT3 inhibited TGF- β stimulated cell growth
mediated by the epidermal growth factor receptor (EGFR).

There remains an unmet need for therapeutic compositions and methods targeting expression of STAT3, and disease processes associated therewith.

5 SUMMARY OF THE INVENTION

The present invention provides oligonucleotides which are targeted to nucleic acids encoding STAT3 and are capable of modulating STAT3 expression. The present invention also provides chimeric oligonucleotides targeted
10 to nucleic acids encoding human STAT3. The oligonucleotides of the invention are believed to be useful both diagnostically and therapeutically, and are believed to be particularly useful in the methods of the present invention.

15 The present invention also comprises methods of modulating the expression of human STAT3, in cells and tissues, using the oligonucleotides of the invention. Methods of inhibiting STAT3 expression are provided; these methods are believed to be useful both therapeutically and
20 diagnostically. These methods are also useful as tools, for example, for detecting and determining the role of STAT3 in various cell functions and physiological processes and conditions and for diagnosing conditions associated with expression of STAT3.

25 The present invention also comprises methods for diagnosing and treating inflammatory diseases, particularly rheumatoid arthritis, and cancers, including those of the breast, prostate, head and neck, and brain, myelomas and melanomas and leukemias and lymphomas. These methods are
30 believed to be useful, for example, in diagnosing STAT3-associated disease progression. These methods employ the oligonucleotides of the invention. These methods are believed to be useful both therapeutically, including prophylactically, and as clinical research and diagnostic
35 tools.

DETAILED DESCRIPTION OF THE INVENTION

STAT3 plays an important role in cytokine signal transduction. Overexpression and/or constitutive activation of STAT3 is associated with a number of inflammatory diseases and cancers. As such, this DNA-binding protein represents an attractive target for treatment of such diseases. In particular, modulation of the expression of STAT3 may be useful for the treatment of diseases such as rheumatoid arthritis, breast cancer, prostate cancer, brain cancer, head and neck cancer, myelomas, melanomas, leukemias and lymphomas.

The present invention employs antisense compounds, particularly oligonucleotides, for use in modulating the function of nucleic acid molecules encoding STAT3, ultimately modulating the amount of STAT3 produced. This is accomplished by providing oligonucleotides which specifically hybridize with nucleic acids, preferably mRNA, encoding STAT3.

This relationship between an antisense compound such as an oligonucleotide and its complementary nucleic acid target, to which it hybridizes, is commonly referred to as "antisense". "Targeting" an oligonucleotide to a chosen nucleic acid target, in the context of this invention, is a multistep process. The process usually begins with identifying a nucleic acid sequence whose function is to be modulated. This may be, as examples, a cellular gene (or mRNA made from the gene) whose expression is associated with a particular disease state, or a foreign nucleic acid from an infectious agent. In the present invention, the targets are nucleic acids encoding STAT3; in other words, a gene encoding STAT3, or mRNA expressed from the STAT3 gene. mRNA which encodes STAT3 is presently the preferred target. The targeting process also includes determination of a site or sites within the nucleic acid sequence for the antisense interaction to occur such that modulation of gene expression will result.

In accordance with this invention, persons of ordinary skill in the art will understand that messenger RNA includes not only the information to encode a protein using the three letter genetic code, but also associated
5 ribonucleotides which form a region known to such persons as the 5'-untranslated region, the 3'-untranslated region, the 5' cap region and intron/exon junction ribonucleotides. Thus, oligonucleotides may be formulated in accordance with this invention which are targeted wholly or in part to
10 these associated ribonucleotides as well as to the informational ribonucleotides. The oligonucleotide may therefore be specifically hybridizable with a transcription initiation site region, a translation initiation codon region, a 5' cap region, an intron/exon junction, coding
15 sequences, a translation termination codon region or sequences in the 5'- or 3'-untranslated region. Since, as is known in the art, the translation initiation codon is typically 5'-AUG (in transcribed mRNA molecules; 5'-ATG in the corresponding DNA molecule), the translation initiation
20 codon is also referred to as the "AUG codon," the "start codon" or the "AUG start codon." A minority of genes have a translation initiation codon having the RNA sequence 5'-GUG, 5'-UUG or 5'-CUG, and 5'-AUA, 5'-ACG and 5'-CUG have been shown to function *in vivo*. Thus, the terms
25 "translation initiation codon" and "start codon" can encompass many codon sequences, even though the initiator amino acid in each instance is typically methionine (in eukaryotes) or formylmethionine (prokaryotes). It is also known in the art that eukaryotic and prokaryotic genes may
30 have two or more alternative start codons, any one of which may be preferentially utilized for translation initiation in a particular cell type or tissue, or under a particular set of conditions. In the context of the invention, "start codon" and "translation initiation codon" refer to the
35 codon or codons that are used *in vivo* to initiate translation of an mRNA molecule transcribed from a gene encoding STAT3, regardless of the sequence(s) of such

codons. It is also known in the art that a translation termination codon (or "stop codon") of a gene may have one of three sequences, i.e., 5'-UAA, 5'-UAG and 5'-UGA (the corresponding DNA sequences are 5'-TAA, 5'-TAG and 5'-TGA, respectively). The terms "start codon region," "AUG region" and "translation initiation codon region" refer to a portion of such an mRNA or gene that encompasses from about 25 to about 50 contiguous nucleotides in either direction (i.e., 5' or 3') from a translation initiation codon. This region is a preferred target region. Similarly, the terms "stop codon region" and "translation termination codon region" refer to a portion of such an mRNA or gene that encompasses from about 25 to about 50 contiguous nucleotides in either direction (i.e., 5' or 3') from a translation termination codon. This region is a preferred target region. The open reading frame (ORF) or "coding region," which is known in the art to refer to the region between the translation initiation codon and the translation termination codon, is also a region which may be targeted effectively. Other preferred target regions include the 5' untranslated region (5'UTR), known in the art to refer to the portion of an mRNA in the 5' direction from the translation initiation codon, and thus including nucleotides between the 5' cap site and the translation initiation codon of an mRNA or corresponding nucleotides on the gene and the 3' untranslated region (3'UTR), known in the art to refer to the portion of an mRNA in the 3' direction from the translation termination codon, and thus including nucleotides between the translation termination codon and 3' end of an mRNA or corresponding nucleotides on the gene. The 5' cap of an mRNA comprises an N7-methylated guanosine residue joined to the 5'-most residue of the mRNA via a 5'-5' triphosphate linkage. The 5' cap region of an mRNA is considered to include the 5' cap structure itself as well as the first 50 nucleotides adjacent to the cap. The 5' cap region may also be a preferred target region.

Although some eukaryotic mRNA transcripts are directly translated, many contain one or more regions, known as "introns", which are excised from a pre-mRNA transcript to yield one or more mature mRNA. The remaining
5 (and therefore translated) regions are known as "exons" and are spliced together to form a continuous mRNA sequence. mRNA splice sites, i.e., exon-exon or intron-exon junctions, may also be preferred target regions, and are particularly useful in situations where aberrant splicing
10 is implicated in disease, or where an overproduction of a particular mRNA splice product is implicated in disease. Aberrant fusion junctions due to rearrangements or deletions are also preferred targets. Targeting particular exons in alternatively spliced mRNAs may also be preferred.
15 It has also been found that introns can also be effective, and therefore preferred, target regions for antisense compounds targeted, for example, to DNA or pre-mRNA.

Once the target site or sites have been identified, oligonucleotides are chosen which are sufficiently
20 complementary to the target, i.e., hybridize sufficiently well and with sufficient specificity, to give the desired modulation.

"Hybridization", in the context of this invention, means hydrogen bonding, also known as Watson-Crick base
25 pairing, between complementary bases, usually on opposite nucleic acid strands or two regions of a nucleic acid strand. Guanine and cytosine are examples of complementary bases which are known to form three hydrogen bonds between them. Adenine and thymine are examples of complementary
30 bases which form two hydrogen bonds between them.

"Specifically hybridizable" and "complementary" are terms which are used to indicate a sufficient degree of complementarity such that stable and specific binding occurs between the DNA or RNA target and the
35 oligonucleotide.

It is understood that an oligonucleotide need not be 100% complementary to its target nucleic acid sequence to

be specifically hybridizable. An oligonucleotide is specifically hybridizable when binding of the oligonucleotide to the target interferes with the normal function of the target molecule to cause a loss of utility, and there is a sufficient degree of complementarity to avoid non-specific binding of the oligonucleotide to non-target sequences under conditions in which specific binding is desired, i.e., under physiological conditions in the case of *in vivo* assays or therapeutic treatment or, in the case of *in vitro* assays, under conditions in which the assays are conducted.

Hybridization of antisense oligonucleotides with mRNA interferes with one or more of the normal functions of mRNA. The functions of mRNA to be interfered with include all vital functions such as, for example, translocation of the RNA to the site of protein translation, translation of protein from the RNA, splicing of the RNA to yield one or more mRNA species, and catalytic activity which may be engaged in by the RNA. Binding of specific protein(s) to the RNA may also be interfered with by antisense oligonucleotide hybridization to the RNA.

The overall effect of interference with mRNA function is modulation of expression of STAT3. In the context of this invention "modulation" means either inhibition or stimulation; i.e., either a decrease or increase in expression. This modulation can be measured in ways which are routine in the art, for example by Northern blot assay of mRNA expression, or reverse transcriptase PCR, as taught in the examples of the instant application or by Western blot or ELISA assay of protein expression, or by an immunoprecipitation assay of protein expression. Effects on cell proliferation or tumor cell growth can also be measured, as taught in the examples of the instant application. Inhibition is presently preferred.

In addition to the well known antisense effects of oligonucleotides, it has also been found that oligonucleotide analogs having at least one

phosphorothioate bond can induce stimulation of a local immune response. This is described in U.S. Patent 5,663,153 which is commonly assigned to the assignee of the present invention and is herein incorporated by reference in its entirety. This immunostimulatory effect does not appear to be related to any antisense effect which these oligonucleotide analogs may or may not possess. These oligonucleotide analogs are useful as immunopotentiators, either alone or in combination with other therapeutic modalities, such as drugs, particularly antiinfective and anticancer drugs, and surgical procedures to increase efficacy. In addition, the antiinfective and anticancer effects already possessed by certain antisense oligonucleotide analogs are enhanced through such immune stimulation.

It has also been found that oligonucleotide analogs having at least one phosphorothioate bond can be used to induce stimulation of a systemic or humoral immune response. Thus, these oligonucleotides are also useful as immunopotentiators of an antibody response, either alone or in combination with other therapeutic modalities. U.S. Patent 5,663,153.

It is presently believed, therefore, that, in addition to the antisense effects of oligonucleotides targeted to STAT3, oligonucleotides containing at least one phosphorothioate backbone linkage may be useful in eliciting an immune response which may add to the antitumor "bystander effect" already observed with dominant negative inhibitors of STAT3 signaling. Niu et al., *Cancer Res.*, 1999, 59, 5059-5063. This effect is believed to be related to tumor infiltration by acute and chronic inflammatory cells which may participate in killing of residual tumor cells. Thus the therapeutic effects of antisense oligonucleotides targeted to STAT3 may be potentiated by the immunostimulatory properties of the oligonucleotides themselves. Alternatively, oligonucleotides which may not be targeted to STAT3 but which contain at least one

phosphorothioate backbone linkage may be used as adjuvants in combination with antisense or other inhibitors of STAT3.

The oligonucleotides of this invention can be used in diagnostics, therapeutics, prophylaxis, and as research
5 reagents and in kits. Since the oligonucleotides of this invention hybridize to nucleic acids encoding STAT3, sandwich, colorimetric and other assays can easily be constructed to exploit this fact. Provision of means for detecting hybridization of oligonucleotide with the STAT3
10 gene or mRNA can routinely be accomplished. Such provision may include enzyme conjugation, radiolabelling or any other suitable detection systems. Kits for detecting the presence or absence of STAT3 may also be prepared.

The present invention is also suitable for diagnosing
15 abnormal inflammatory states or certain cancers in tissue or other samples from patients suspected of having an inflammatory disease such as rheumatoid arthritis or cancers such as breast, brain, or head and neck cancer, melanomas, myelomas, leukemias and lymphomas. A number of
20 assays may be formulated employing the present invention, which assays will commonly comprise contacting a tissue sample with an oligonucleotide of the invention under conditions selected to permit detection and, usually, quantitation of such inhibition. In the context of this
25 invention, to "contact" tissues or cells with an oligonucleotide or oligonucleotides means to add the oligonucleotide(s), usually in a liquid carrier, to a cell suspension or tissue sample, either *in vitro* or *ex vivo*, or to administer the oligonucleotide(s) to cells or tissues
30 within an animal.

The oligonucleotides of this invention may also be used for research purposes. Thus, the specific hybridization exhibited by the oligonucleotides may be used for assays, purifications, cellular product preparations
35 and in other methodologies which may be appreciated by persons of ordinary skill in the art.

In the context of this invention, the term "oligonucleotide" refers to an oligomer or polymer of ribonucleic acid or deoxyribonucleic acid. This term includes oligonucleotides composed of naturally-occurring nucleobases, sugars and covalent intersugar (backbone) linkages as well as oligonucleotides having non-naturally-occurring portions which function similarly. Such modified or substituted oligonucleotides are often preferred over native forms because of desirable properties such as, for example, enhanced cellular uptake, enhanced binding to target and increased stability in the presence of nucleases.

The antisense compounds in accordance with this invention preferably comprise from about 5 to about 50 nucleobases. Particularly preferred are antisense oligonucleotides comprising from about 8 to about 30 nucleobases (i.e. from about 8 to about 30 linked nucleosides). As is known in the art, a nucleoside is a base-sugar combination. The base portion of the nucleoside is normally a heterocyclic base. The two most common classes of such heterocyclic bases are the purines and the pyrimidines. Nucleotides are nucleosides that further include a phosphate group covalently linked to the sugar portion of the nucleoside. For those nucleosides that include a pentofuranosyl sugar, the phosphate group can be linked to either the 2=, 3= or 5= hydroxyl moiety of the sugar. In forming oligonucleotides, the phosphate groups covalently link adjacent nucleosides to one another to form a linear polymeric compound. In turn the respective ends of this linear polymeric structure can be further joined to form a circular structure, however, open linear structures are generally preferred. Within the oligonucleotide structure, the phosphate groups are commonly referred to as forming the internucleoside backbone of the oligonucleotide. The normal linkage or backbone of RNA and DNA is a 3= to 5= phosphodiester linkage.

While the preferred form of antisense compound is a single-stranded antisense oligonucleotide, in many species the introduction of double-stranded structures, such as double-stranded RNA (dsRNA) molecules, has been shown to induce potent and specific antisense-mediated reduction of the function of a gene or its associated gene products. This phenomenon occurs in both plants and animals and is believed to have an evolutionary connection to viral defense and transposon silencing.

The first evidence that dsRNA could lead to gene silencing in animals came in 1995 from work in the nematode, *Caenorhabditis elegans* (Guo and Kempheus, *Cell*, 1995, 81, 611-620). Montgomery et al. have shown that the primary interference effects of dsRNA are posttranscriptional (Montgomery et al., *Proc. Natl. Acad. Sci. USA*, 1998, 95, 15502-15507). The posttranscriptional antisense mechanism defined in *Caenorhabditis elegans* resulting from exposure to double-stranded RNA (dsRNA) has since been designated RNA interference (RNAi). This term has been generalized to mean antisense-mediated gene silencing involving the introduction of dsRNA leading to the sequence-specific reduction of endogenous targeted mRNA levels (Fire et al., *Nature*, 1998, 391, 806-811). Recently, it has been shown that it is, in fact, the single-stranded RNA oligomers of antisense polarity of the dsRNAs which are the potent inducers of RNAi (Tijsterman et al., *Science*, 2002, 295, 694-697). The use of these double stranded RNA molecules (short interfering RNA or siRNA) for targeting and inhibiting the expression of STAT3 mRNA is also contemplated. These double stranded RNA molecules target regions similar to those targeted by antisense oligonucleotides and have similar effects. These double stranded RNA molecules are generally 19-21 base pairs in length, but may range between 8 and 50 nucleobases. The production of siRNA molecules is described in a general sense in the examples provided below, but it will be appreciated that any desired siRNA targeted to STAT3 may be synthesized by

conventional oligonucleotide synthesis techniques. Once the sequence of the antisense strand is known, the complementary sense strand is synthesized based on base pairing. The sense and antisense strands are then combined to form the siRNA.

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Oligomer and Monomer Modifications

As is known in the art, a nucleoside is a base-sugar combination. The base portion of the nucleoside is normally a heterocyclic base. The two most common classes of such heterocyclic bases are the purines and the pyrimidines. Nucleotides are nucleosides that further include a phosphate group covalently linked to the sugar portion of the nucleoside. For those nucleosides that include a pentofuranosyl sugar, the phosphate group can be linked to either the 2', 3' or 5' hydroxyl moiety of the sugar. In forming oligonucleotides, the phosphate groups covalently link adjacent nucleosides to one another to form a linear polymeric compound. In turn, the respective ends of this linear polymeric compound can be further joined to form a circular compound, however, linear compounds are generally preferred. In addition, linear compounds may have internal nucleobase complementarity and may therefore fold in a manner as to produce a fully or partially double-stranded compound. Within oligonucleotides, the phosphate groups are commonly referred to as forming the internucleoside linkage or in conjunction with the sugar ring the backbone of the oligonucleotide. The normal internucleoside linkage that makes up the backbone of RNA and DNA is a 3' to 5' phosphodiester linkage.

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Modified Internucleoside Linkages

Specific examples of preferred antisense oligomeric compounds useful in this invention include oligonucleotides containing modified e.g. non-naturally occurring internucleoside linkages. As defined in this specification, oligonucleotides having modified internucleoside linkages include internucleoside linkages

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that retain a phosphorus atom and internucleoside linkages that do not have a phosphorus atom. For the purposes of this specification, and as sometimes referenced in the art, modified oligonucleotides that do not have a phosphorus
5 atom in their internucleoside backbone can also be considered to be oligonucleosides.

In the *C. elegans* system, modification of the internucleotide linkage (phosphorothioate) did not significantly interfere with RNAi activity. Based on this
10 observation, it is suggested that certain preferred oligomeric compounds of the invention can also have one or more modified internucleoside linkages. A preferred phosphorus containing modified internucleoside linkage is the phosphorothioate internucleoside linkage.

15 Preferred modified oligonucleotide backbones containing a phosphorus atom therein include, for example, phosphorothioates, chiral phosphorothioates, phosphorodithioates, phosphotriesters, aminoalkylphosphotriesters, methyl and other alkyl phosphonates including 3'-alkylene
20 phosphonates, 5'-alkylene phosphonates and chiral phosphonates, phosphinates, phosphoramidates including 3'-amino phosphoramidate and aminoalkylphosphoramidates, thionophosphoramidates, thionoalkylphosphonates, thionoalkylphosphotriesters, selenophosphates and borano-
25 phosphates having normal 3'-5' linkages, 2'-5' linked analogs of these, and those having inverted polarity wherein one or more internucleotide linkages is a 3' to 3', 5' to 5' or 2' to 2' linkage. Preferred oligonucleotides having inverted polarity comprise a single 3' to 3' linkage
30 at the 3'-most internucleotide linkage i.e. a single inverted nucleoside residue which may be abasic (the nucleobase is missing or has a hydroxyl group in place thereof). Various salts, mixed salts and free acid forms are also included.

35 Representative United States patents that teach the preparation of the above phosphorus-containing linkages include, but are not limited to, U.S.: 3,687,808;

4,469,863; 4,476,301; 5,023,243; 5,177,196; 5,188,897;
5,264,423; 5,276,019; 5,278,302; 5,286,717; 5,321,131;
5,399,676; 5,405,939; 5,453,496; 5,455,233; 5,466,677;
5,476,925; 5,519,126; 5,536,821; 5,541,306; 5,550,111;
5 5,563,253; 5,571,799; 5,587,361; 5,194,599; 5,565,555;
5,527,899; 5,721,218; 5,672,697 and 5,625,050, certain of
which are commonly owned with this application, and each of
which is herein incorporated by reference.

In more preferred embodiments of the invention,
10 oligomeric compounds have one or more phosphorothioate
and/or heteroatom internucleoside linkages, in particular -
CH₂-NH-O-CH₂-, -CH₂-N(CH₃)-O-CH₂- [known as a methylene
(methylimino) or MMI backbone], -CH₂-O-N(CH₃)-CH₂-, -CH₂-
N(CH₃)-N(CH₃)-CH₂- and -O-N(CH₃)-CH₂-CH₂- [wherein the native
15 phosphodiester internucleotide linkage is represented as -
O-P(=O)(OH)-O-CH₂-]. The MMI type internucleoside linkages
are disclosed in the above referenced U.S. patent
5,489,677. Preferred amide internucleoside linkages are
disclosed in the above referenced U.S. patent 5,602,240.

20 Preferred modified oligonucleotide backbones that do
not include a phosphorus atom therein have backbones that
are formed by short chain alkyl or cycloalkyl
internucleoside linkages, mixed heteroatom and alkyl or
cycloalkyl internucleoside linkages, or one or more short
25 chain heteroatomic or heterocyclic internucleoside
linkages. These include those having morpholino linkages
(formed in part from the sugar portion of a nucleoside);
siloxane backbones; sulfide, sulfoxide and sulfone
backbones; formacetyl and thioformacetyl backbones;
30 methylene formacetyl and thioformacetyl backbones;
riboacetyl backbones; alkene containing backbones;
sulfamate backbones; methyleneimino and methylenehydrazino
backbones; sulfonate and sulfonamide backbones; amide
backbones; and others having mixed N, O, S and CH₂ component
35 parts.

Representative United States patents that teach the
preparation of the above oligonucleosides include, but are

not limited to, U.S.: 5,034,506; 5,166,315; 5,185,444;
5,214,134; 5,216,141; 5,235,033; 5,264,562; 5,264,564;
5,405,938; 5,434,257; 5,466,677; 5,470,967; 5,489,677;
5,541,307; 5,561,225; 5,596,086; 5,602,240; 5,610,289;
5 5,602,240; 5,608,046; 5,610,289; 5,618,704; 5,623,070;
5,663,312; 5,633,360; 5,677,437; 5,792,608; 5,646,269 and
5,677,439, certain of which are commonly owned with this
application, and each of which is herein incorporated by
reference.

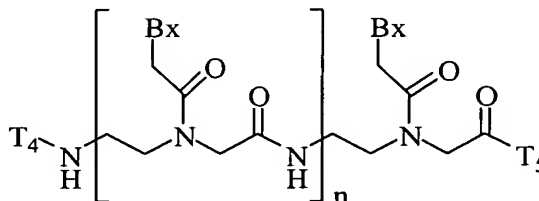
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Oligomer Mimetics

Another preferred group of oligomeric compounds
amenable to the present invention includes oligonucleotide
mimetics. The term mimetic as it is applied to
15 oligonucleotides is intended to include oligomeric
compounds wherein only the furanose ring or both the
furanose ring and the internucleotide linkage are replaced
with novel groups, replacement of only the furanose ring is
also referred to in the art as being a sugar surrogate.
20 The heterocyclic base moiety or a modified heterocyclic
base moiety is maintained for hybridization with an
appropriate target nucleic acid. One such oligomeric
compound, an oligonucleotide mimetic that has been shown to
have excellent hybridization properties, is referred to as
25 a peptide nucleic acid (PNA). In PNA oligomeric compounds,
the sugar-backbone of an oligonucleotide is replaced with
an amide containing backbone, in particular an
aminoethylglycine backbone. The nucleobases are retained
and are bound directly or indirectly to aza nitrogen atoms
30 of the amide portion of the backbone. Representative
United States patents that teach the preparation of PNA
oligomeric compounds include, but are not limited to, U.S.:
5,539,082; 5,714,331; and 5,719,262, each of which is
herein incorporated by reference. Further teaching of PNA
35 oligomeric compounds can be found in Nielsen et al.,
Science, 1991, 254, 1497-1500.

One oligonucleotide mimetic that has been reported to have excellent hybridization properties is peptide nucleic acids (PNA). The backbone in PNA compounds is two or more linked aminoethylglycine units which gives PNA an amide containing backbone. The heterocyclic base moieties are bound directly or indirectly to aza nitrogen atoms of the amide portion of the backbone. Representative United States patents that teach the preparation of PNA compounds include, but are not limited to, U.S.: 5,539,082; 5,714,331; and 5,719,262, each of which is herein incorporated by reference. Further teaching of PNA compounds can be found in Nielsen et al., Science, 1991, 254, 1497-1500.

PNA has been modified to incorporate numerous modifications since the basic PNA structure was first prepared. The basic structure is shown below:



wherein

Bx is a heterocyclic base moiety;

T_4 is hydrogen, an amino protecting group, ---C(O)R_5 , substituted or unsubstituted $\text{C}_1\text{---C}_{10}$ alkyl, substituted or unsubstituted $\text{C}_2\text{---C}_{10}$ alkenyl, substituted or unsubstituted $\text{C}_2\text{---C}_{10}$ alkynyl, alkylsulfonyl, arylsulfonyl, a chemical functional group, a reporter group, a conjugate group, a D or L α -amino acid linked via the α -carboxyl group or optionally through the ω -carboxyl group when the amino acid is aspartic acid or glutamic acid or a peptide derived from D, L or mixed D and L amino acids linked through a carboxyl group, wherein the substituent groups are selected from hydroxyl, amino, alkoxy, carboxy, benzyl, phenyl, nitro, thiol, thioalkoxy, halogen, alkyl, aryl, alkenyl and alkynyl;

T_5 is -OH, -N(Z_1) Z_2 , R_5 , D or L α -amino acid linked via the α -amino group or optionally through the ω -amino group when the amino acid is lysine or ornithine or a peptide derived from D, L or mixed D and L amino acids linked
5 through an amino group, a chemical functional group, a reporter group or a conjugate group;

Z_1 is hydrogen, C_1 - C_6 alkyl, or an amino protecting group;

Z_2 is hydrogen, C_1 - C_6 alkyl, an amino protecting group,
10 -C(=O)-(CH₂)_n-J- Z_3 , a D or L α -amino acid linked via the α -carboxyl group or optionally through the ω -carboxyl group when the amino acid is aspartic acid or glutamic acid or a peptide derived from D, L or mixed D and L amino acids linked through a carboxyl group;

15 Z_3 is hydrogen, an amino protecting group, - C_1 - C_6 alkyl, -C(=O)-CH₃, benzyl, benzoyl, or -(CH₂)_n-N(H) Z_1 ;

each J is O, S or NH;

R_5 is a carbonyl protecting group; and

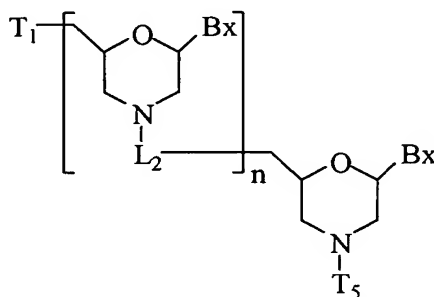
n is from 2 to about 50.

20 Another class of oligonucleotide mimetic that has been studied is based on linked morpholino units (morpholino nucleic acid) having heterocyclic bases attached to the morpholino ring. A number of linking groups have been reported that link the morpholino monomeric units in a
25 morpholino nucleic acid. A preferred class of linking groups have been selected to give a non-ionic oligomeric compound. The non-ionic morpholino-based oligomeric compounds are less likely to have undesired interactions with cellular proteins. Morpholino-based oligomeric
30 compounds are non-ionic mimics of oligonucleotides which are less likely to form undesired interactions with cellular proteins (Dwaine A. Braasch and David R. Corey, *Biochemistry*, 2002, 41(14), 4503-4510). Morpholino-based oligomeric compounds are disclosed in United States Patent
35 5,034,506, issued July 23, 1991. The morpholino class of oligomeric compounds have been prepared having a variety of

different linking groups joining the monomeric subunits.

Morpholino nucleic acids have been prepared having a variety of different linking groups (L_2) joining the monomeric subunits. The basic formula is shown below:

5



wherein

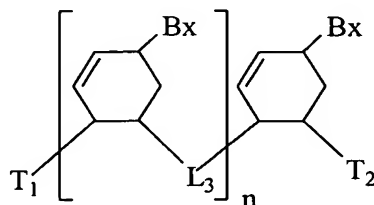
- 10 T_1 is hydroxyl or a protected hydroxyl;
 T_5 is hydrogen or a phosphate or phosphate derivative;
 L_2 is a linking group; and
 n is from 2 to about 50.

A further class of oligonucleotide mimetic is referred
15 to as cyclohexenyl nucleic acids (CeNA). The furanose ring
normally present in an DNA/RNA molecule is replaced with a
cyclohexenyl ring. CeNA DMT protected phosphoramidite
monomers have been prepared and used for oligomeric
compound synthesis following classical phosphoramidite
20 chemistry. Fully modified CeNA oligomeric compounds and
oligonucleotides having specific positions modified with
CeNA have been prepared and studied (see Wang et al., *J.*
Am. Chem. Soc., **2000**, 122, 8595-8602). In general the
incorporation of CeNA monomers into a DNA chain increases
25 its stability of a DNA/RNA hybrid. CeNA oligoadenylates
formed complexes with RNA and DNA complements with similar
stability to the native complexes. The study of
incorporating CeNA structures into natural nucleic acid
structures was shown by NMR and circular dichroism to
30 proceed with easy conformational adaptation. Furthermore

the incorporation of CeNA into a sequence targeting RNA was stable to serum and able to activate E. Coli RNase resulting in cleavage of the target RNA strand.

The general formula of CeNA is shown below:

5



wherein

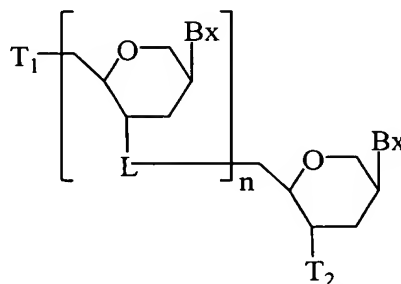
each Bx is a heterocyclic base moiety;

10 T_1 is hydroxyl or a protected hydroxyl; and

T_2 is hydroxyl or a protected hydroxyl.

Another class of oligonucleotide mimetic (anhydrohexitol nucleic acid) can be prepared from one or more anhydrohexitol nucleosides (see, Wouters and

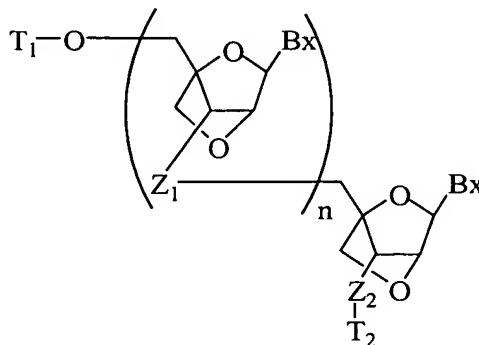
15 Herdewijn, *Bioorg. Med. Chem. Lett.*, 1999, 9, 1563-1566) and would have the general formula:



A further preferred modification includes Locked
20 Nucleic Acids (LNAs) in which the 2'-hydroxyl group is linked to the 4' carbon atom of the sugar ring thereby forming a 2'-C,4'-C-oxymethylene linkage thereby forming a bicyclic sugar moiety. The linkage is preferably a methylene $(-CH_2-)_n$ group bridging the 2' oxygen atom and the
25 4' carbon atom wherein n is 1 or 2 (Singh et al., *Chem. Commun.*, 1998, 4, 455-456). LNA and LNA analogs display very high duplex thermal stabilities with complementary DNA

and RNA ($T_m = +3$ to $+10$ C), stability towards 3'-exonucleolytic degradation and good solubility properties. The basic structure of LNA showing the bicyclic ring system is shown below:

5



The conformations of LNAs determined by 2D NMR spectroscopy have shown that the locked orientation of the LNA nucleotides, both in single-stranded LNA and in duplexes, constrains the phosphate backbone in such a way as to introduce a higher population of the N-type conformation (Petersen et al., J. Mol. Recognit., 2000, 13, 44-53). These conformations are associated with improved stacking of the nucleobases (Wengel et al., Nucleosides Nucleotides, 1999, 18, 1365-1370).

LNA has been shown to form exceedingly stable LNA:LNA duplexes (Koshkin et al., J. Am. Chem. Soc., 1998, 120, 13252-13253). LNA:LNA hybridization was shown to be the most thermally stable nucleic acid type duplex system, and the RNA-mimicking character of LNA was established at the duplex level. Introduction of 3 LNA monomers (T or A) significantly increased melting points ($T_m = +15/+11$) toward DNA complements. The universality of LNA-mediated hybridization has been stressed by the formation of exceedingly stable LNA:LNA duplexes. The RNA-mimicking of LNA was reflected with regard to the N-type conformational restriction of the monomers and to the secondary structure of the LNA:RNA duplex.

LNAs also form duplexes with complementary DNA, RNA or LNA with high thermal affinities. Circular dichroism (CD) spectra show that duplexes involving fully modified LNA (esp. LNA:RNA) structurally resemble an A-form RNA:RNA duplex. Nuclear magnetic resonance (NMR) examination of an LNA:DNA duplex confirmed the 3'-endo conformation of an LNA monomer. Recognition of double-stranded DNA has also been demonstrated suggesting strand invasion by LNA. Studies of mismatched sequences show that LNAs obey the Watson-Crick base pairing rules with generally improved selectivity compared to the corresponding unmodified reference strands.

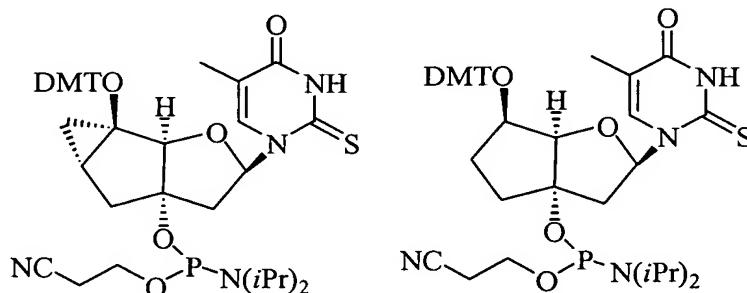
Novel types of LNA-oligomeric compounds, as well as the LNAs, are useful in a wide range of diagnostic and therapeutic applications. Among these are antisense applications, PCR applications, strand-displacement oligomers, substrates for nucleic acid polymerases and generally as nucleotide based drugs. Potent and nontoxic antisense oligonucleotides containing LNAs have been described (Wahlestedt et al., Proc. Natl. Acad. Sci. U. S. A., 2000, 97, 5633-5638.) The authors have demonstrated that LNAs confer several desired properties to antisense agents. LNA/DNA copolymers were not degraded readily in blood serum and cell extracts. LNA/DNA copolymers exhibited potent antisense activity in assay systems as disparate as G-protein-coupled receptor signaling in living rat brain and detection of reporter genes in *Escherichia coli*. Lipofectin-mediated efficient delivery of LNA into living human breast cancer cells has also been accomplished.

The synthesis and preparation of the LNA monomers adenine, cytosine, guanine, 5-methyl-cytosine, thymine and uracil, along with their oligomerization, and nucleic acid recognition properties have been described (Koshkin et al., Tetrahedron, 1998, 54, 3607-3630). LNAs and preparation thereof are also described in WO 98/39352 and WO 99/14226.

The first analogs of LNA, phosphorothioate-LNA and 2'-thio-LNAs, have also been prepared (Kumar et al., Bioorg.

Med. Chem. Lett., 1998, 8, 2219-2222). Preparation of locked nucleoside analogs containing oligodeoxyribonucleotide duplexes as substrates for nucleic acid polymerases has also been described (Wengel et al.,
5 PCT International Application WO 98-DK393 19980914). Furthermore, synthesis of 2'-amino-LNA, a novel conformationally restricted high-affinity oligonucleotide analog with a handle has been described in the art (Singh et al., J. Org. Chem., 1998, 63, 10035-10039). In
10 addition, 2'-Amino- and 2'-methylamino-LNA's have been prepared and the thermal stability of their duplexes with complementary RNA and DNA strands has been previously reported.

Further oligonucleotide mimetics have been prepared to
15 include bicyclic and tricyclic nucleoside analogs having the formulas (amidite monomers shown):

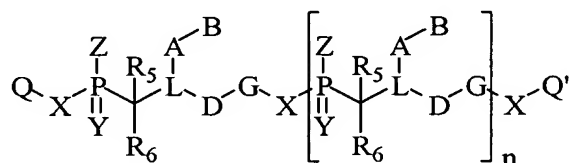


(see Steffens et al., *Helv. Chim. Acta*, 1997, 80, 2426-
20 2439; Steffens et al., *J. Am. Chem. Soc.*, 1999, 121, 3249-3255; and Renneberg et al., *J. Am. Chem. Soc.*, 2002, 124, 5993-6002). These modified nucleoside analogs have been oligomerized using the phosphoramidite approach and the resulting oligomeric compounds containing tricyclic
25 nucleoside analogs have shown increased thermal stabilities (T_m's) when hybridized to DNA, RNA and itself. Oligomeric compounds containing bicyclic nucleoside analogs have shown thermal stabilities approaching that of DNA duplexes.

Another class of oligonucleotide mimetic is referred
30 to as phosphonomonoester nucleic acids incorporate a

phosphorus group in a backbone the backbone. This class of
oligonucleotide mimetic is reported to have useful physical
and biological and pharmacological properties in the areas
of inhibiting gene expression (antisense oligonucleotides,
5 ribozymes, sense oligonucleotides and triplex-forming
oligonucleotides), as probes for the detection of nucleic
acids and as auxiliaries for use in molecular biology.

The general formula (for definitions of Markush
variables see: United States Patents 5,874,553 and
10 6,127,346 herein incorporated by reference in their
entirety) is shown below.



Another oligonucleotide mimetic has been reported
15 wherein the furanosyl ring has been replaced by a
cyclobutyl moiety.

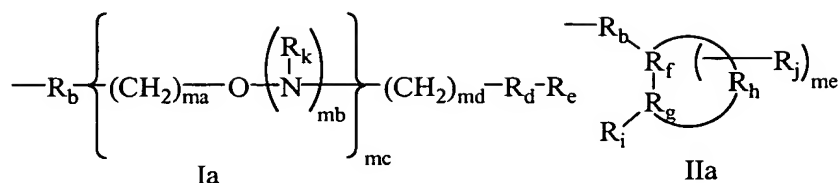
Modified sugars

Oligomeric compounds of the invention may also contain
20 one or more substituted sugar moieties. Preferred
oligomeric compounds comprise a sugar substituent group
selected from: OH; F; O-, S-, or N-alkyl; O-, S-, or N-
alkenyl; O-, S- or N-alkynyl; or O-alkyl-O-alkyl, wherein
the alkyl, alkenyl and alkynyl may be substituted or
25 unsubstituted C₁ to C₁₀ alkyl or C₂ to C₁₀ alkenyl and
alkynyl. Particularly preferred are O[(CH₂)_nO]_mCH₃,
O(CH₂)_nOCH₃, O(CH₂)_nNH₂, O(CH₂)_nCH₃, O(CH₂)_nONH₂, and
O(CH₂)_nON[(CH₂)_nCH₃]₂, where n and m are from 1 to about 10.
Other preferred oligonucleotides comprise a sugar
30 substituent group selected from: C₁ to C₁₀ lower alkyl,
substituted lower alkyl, alkenyl, alkynyl, alkaryl,
aralkyl, O-alkaryl or O-aralkyl, SH, SCH₃, OCN, Cl, Br, CN,
CF₃, OCF₃, SOCH₃, SO₂CH₃, ONO₂, NO₂, N₃, NH₂, heterocycloalkyl,
heterocycloalkaryl, aminoalkylamino, polyalkylamino,

substituted silyl, an RNA cleaving group, a reporter group, an intercalator, a group for improving the pharmacokinetic properties of an oligonucleotide, or a group for improving the pharmacodynamic properties of an oligonucleotide, and
5 other substituents having similar properties. A preferred modification includes 2'-methoxyethoxy (2'-O-CH₂CH₂OCH₃, also known as 2'-O-(2-methoxyethyl) or 2'-MOE) (Martin et al., *Helv. Chim. Acta*, 1995, 78, 486-504) i.e., an alkoxyalkoxy group. A further preferred modification includes 2'-
10 dimethylaminoxyethoxy, i.e., a O(CH₂)₂ON(CH₃)₂ group, also known as 2'-DMAOE, as described in examples hereinbelow, and 2'-dimethylaminoethoxyethoxy (also known in the art as 2'-O-dimethyl-amino-ethoxy-ethyl or 2'-DMAEOE), i.e., 2'-O-CH₂-O-CH₂-N(CH₃)₂.

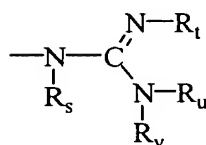
15 Other preferred sugar substituent groups include methoxy (-O-CH₃), aminopropoxy (-OCH₂CH₂CH₂NH₂), allyl (-CH₂-CH=CH₂), -O-allyl (-O-CH₂-CH=CH₂) and fluoro (F). 2'-Sugar substituent groups may be in the arabino (up) position or ribo (down) position. A preferred 2'-arabino modification
20 is 2'-F. Similar modifications may also be made at other positions on the oligomeric compound, particularly the 3' position of the sugar on the 3' terminal nucleoside or in 2'-5' linked oligonucleotides and the 5' position of 5' terminal nucleotide. Oligomeric compounds may also have
25 sugar mimetics such as cyclobutyl moieties in place of the pentofuranosyl sugar. Representative United States patents that teach the preparation of such modified sugar structures include, but are not limited to, U.S.:
4,981,957; 5,118,800; 5,319,080; 5,359,044; 5,393,878;
30 5,446,137; 5,466,786; 5,514,785; 5,519,134; 5,567,811;
5,576,427; 5,591,722; 5,597,909; 5,610,300; 5,627,053;
5,639,873; 5,646,265; 5,658,873; 5,670,633; 5,792,747; and
5,700,920, certain of which are commonly owned with the instant application, and each of which is herein
35 incorporated by reference in its entirety.

Further representative sugar substituent groups include groups of formula I_a or II_a:



wherein:

- R_b is O, S or NH;
 R_d is a single bond, O, S or C(=O);
 R_e is C₁-C₁₀ alkyl, N(R_k)(R_m), N(R_k)(R_n), N=C(R_p)(R_q),
 N=C(R_p)(R_r) or has formula IIIa;



IIIa

- R_p and R_q are each independently hydrogen or C₁-C₁₀
 alkyl;
 R_r is -R_x-R_y;
 each R_s, R_t, R_u and R_v is, independently, hydrogen,
 C(O)R_w, substituted or unsubstituted C₁-C₁₀ alkyl,
 substituted or unsubstituted C₂-C₁₀ alkenyl, substituted or
 unsubstituted C₂-C₁₀ alkynyl, alkylsulfonyl, arylsulfonyl, a
 chemical functional group or a conjugate group, wherein the
 substituent groups are selected from hydroxyl, amino,
 alkoxy, carboxy, benzyl, phenyl, nitro, thiol, thioalkoxy,
 halogen, alkyl, aryl, alkenyl and alkynyl;
 or optionally, R_u and R_v, together form a phthalimido
 moiety with the nitrogen atom to which they are attached;
 each R_w is, independently, substituted or unsubstituted
 C₁-C₁₀ alkyl, trifluoromethyl, cyanoethoxy, methoxy,
 ethoxy, t-butoxy, allyloxy, 9-fluorenylmethoxy, 2-
 (trimethylsilyl)-ethoxy, 2,2,2-trichloroethoxy, benzyloxy,
 butyryl, iso-butyryl, phenyl or aryl;
 R_x is hydrogen, a nitrogen protecting group or -R_x-R_y;
 R_p is hydrogen, a nitrogen protecting group or -R_x-R_y;
 R_x is a bond or a linking moiety;

R_y is a chemical functional group, a conjugate group or a solid support medium;

each R_m and R_n is, independently, H, a nitrogen protecting group, substituted or unsubstituted C_1 - C_{10} alkyl, substituted or unsubstituted C_2 - C_{10} alkenyl, substituted or unsubstituted C_2 - C_{10} alkynyl, wherein the substituent groups are selected from hydroxyl, amino, alkoxy, carboxy, benzyl, phenyl, nitro, thiol, thioalkoxy, halogen, alkyl, aryl, alkenyl, alkynyl; NH_3^+ , $N(R_u)(R_v)$, guanidino and acyl where said acyl is an acid amide or an ester;

or R_m and R_n , together, are a nitrogen protecting group, are joined in a ring structure that optionally includes an additional heteroatom selected from N and O or are a chemical functional group;

R_i is OR_z , SR_z , or $N(R_z)_2$;

each R_z is, independently, H, C_1 - C_8 alkyl, C_1 - C_8 haloalkyl, $C(=NH)N(H)R_u$, $C(=O)N(H)R_u$ or $OC(=O)N(H)R_u$;

R_f , R_g and R_h comprise a ring system having from about 4 to about 7 carbon atoms or having from about 3 to about 6 carbon atoms and 1 or 2 heteroatoms wherein said heteroatoms are selected from oxygen, nitrogen and sulfur and wherein said ring system is aliphatic, unsaturated aliphatic, aromatic, or saturated or unsaturated heterocyclic;

R_j is alkyl or haloalkyl having 1 to about 10 carbon atoms, alkenyl having 2 to about 10 carbon atoms, alkynyl having 2 to about 10 carbon atoms, aryl having 6 to about 14 carbon atoms, $N(R_k)(R_m)$, OR_k , halo, SR_k or CN;

m_a is 1 to about 10;

each m_b is, independently, 0 or 1;

m_c is 0 or an integer from 1 to 10;

m_d is an integer from 1 to 10;

m_e is from 0, 1 or 2; and

provided that when m_c is 0, m_d is greater than 1.

Representative substituents groups of Formula I are disclosed in United States Patent Application Serial No. 09/130,973, filed August 7, 1998, entitled "Capped

2'-Oxyethoxy Oligonucleotides," hereby incorporated by reference in its entirety.

Representative cyclic substituent groups of Formula II are disclosed in United States Patent Application Serial
5 No. 09/123,108, filed July 27, 1998, entitled "RNA Targeted 2'-Oligomeric compounds that are Conformationally Preorganized," hereby incorporated by reference in its entirety.

Particularly preferred sugar substituent groups
10 include $O[(CH_2)_nO]_mCH_3$, $O(CH_2)_nOCH_3$, $O(CH_2)_nNH_2$, $O(CH_2)_nCH_3$, $O(CH_2)_nONH_2$, and $O(CH_2)_nON[(CH_2)_nCH_3]_2$, where n and m are from 1 to about 10.

Representative guanidino substituent groups that are shown in formula III and IV are disclosed in co-owned
15 United States Patent Application 09/349,040, entitled "Functionalized Oligomers", filed July 7, 1999, hereby incorporated by reference in its entirety.

Representative acetamido substituent groups are disclosed in United States Patent 6,147,200 which is hereby
20 incorporated by reference in its entirety.

Representative dimethylaminoethoxyethyl substituent groups are disclosed in International Patent Application PCT/US99/17895, entitled "2'-O-Dimethylaminoethoxyethyl-Oligomeric compounds", filed August 6, 1999, hereby
25 incorporated by reference in its entirety.

Modified Nucleobases/Naturally occurring nucleobases

Oligomeric compounds may also include nucleobase (often referred to in the art simply as "base" or
30 "heterocyclic base moiety") modifications or substitutions.

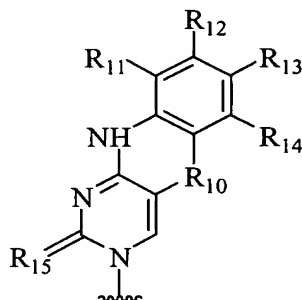
As used herein, "unmodified" or "natural" nucleobases include the purine bases adenine (A) and guanine (G), and the pyrimidine bases thymine (T), cytosine (C) and uracil (U). Modified nucleobases also referred herein as
35 heterocyclic base moieties include other synthetic and natural nucleobases such as 5-methylcytosine (5-me-C), 5-hydroxymethyl cytosine, xanthine, hypoxanthine, 2-

aminoadenine, 6-methyl and other alkyl derivatives of adenine and guanine, 2-propyl and other alkyl derivatives of adenine and guanine, 2-thiouracil, 2-thiothymine and 2-thiocytosine, 5-halouracil and cytosine, 5-propynyl ($-C\equiv C-$ CH₃) uracil and cytosine and other alkynyl derivatives of pyrimidine bases, 6-azo uracil, cytosine and thymine, 5-uracil (pseudouracil), 4-thiouracil, 8-halo, 8-amino, 8-thiol, 8-thioalkyl, 8-hydroxyl and other 8-substituted adenines and guanines, 5-halo particularly 5-bromo, 5-trifluoromethyl and other 5-substituted uracils and cytosines, 7-methylguanine and 7-methyladenine, 2-F-adenine, 2-amino-adenine, 8-azaguanine and 8-azaadenine, 7-deazaguanine and 7-deazaadenine and 3-deazaguanine and 3-deazaadenine.

Heterocyclic base moieties may also include those in which the purine or pyrimidine base is replaced with other heterocycles, for example 7-deaza-adenine, 7-deazaguanosine, 2-aminopyridine and 2-pyridone. Further nucleobases include those disclosed in United States Patent No. 3,687,808, those disclosed in *The Concise Encyclopedia Of Polymer Science And Engineering*, pages 858-859, Kroschwitz, J.I., ed. John Wiley & Sons, 1990, those disclosed by Englisch et al., *Angewandte Chemie*, International Edition, 1991, 30, 613, and those disclosed by Sanghvi, Y.S., Chapter 15, *Antisense Research and Applications*, pages 289-302, Crooke, S.T. and Lebleu, B., ed., CRC Press, 1993. Certain of these nucleobases are particularly useful for increasing the binding affinity of the oligomeric compounds of the invention. These include 5-substituted pyrimidines, 6-azapyrimidines and N-2, N-6 and O-6 substituted purines, including 2-aminopropyl-adenine, 5-propynyluracil and 5-propynylcytosine. 5-methylcytosine substitutions have been shown to increase nucleic acid duplex stability by 0.6-1.2°C (Sanghvi, Y.S., Crooke, S.T. and Lebleu, B., eds., *Antisense Research and*

Applications, CRC Press, Boca Raton, 1993, pp. 276-278) and are presently preferred base substitutions, even more particularly when combined with 2'-O-methoxyethyl sugar modifications.

5 In one aspect of the present invention oligomeric compounds are prepared having polycyclic heterocyclic compounds in place of one or more heterocyclic base moieties. A number of tricyclic heterocyclic compounds have been previously reported. These compounds are
10 routinely used in antisense applications to increase the binding properties of the modified strand to a target strand. The most studied modifications are targeted to guanosines hence they have been termed G-clamps or cytidine analogs. Many of these polycyclic heterocyclic compounds
15 have the general formula:



Representative cytosine analogs that make 3 hydrogen
20 bonds with a guanosine in a second strand include 1,3-diazaphenoxazine-2-one ($R_{10} = O$, $R_{11} - R_{14} = H$) [Kurchavov, et al., *Nucleosides and Nucleotides*, 1997, 16, 1837-1846], 1,3-diazaphenothiazine-2-one ($R_{10} = S$, $R_{11} - R_{14} = H$), [Lin, K.-Y.; Jones, R. J.; Matteucci, M. J. Am. Chem. Soc. 1995,
25 117, 3873-3874] and 6,7,8,9-tetrafluoro-1,3-diazaphenoxazine-2-one ($R_{10} = O$, $R_{11} - R_{14} = F$) [Wang, J.; Lin, K.-Y., Matteucci, M. *Tetrahedron Lett.* 1998, 39, 8385-8388]. Incorporated into oligonucleotides these base modifications were shown to hybridize with complementary
30 guanine and the latter was also shown to hybridize with

adenine and to enhance helical thermal stability by extended stacking interactions (also see U.S. Patent Application entitled "Modified Peptide Nucleic Acids" filed May 24, 2002, Serial number 10/155,920; and U.S. Patent Application entitled "Nuclease Resistant Chimeric Oligonucleotides" filed May 24, 2002, Serial number 10/013,295, both of which are commonly owned with this application and are herein incorporated by reference in their entirety).

Further helix-stabilizing properties have been observed when a cytosine analog/substitute has an aminoethoxy moiety attached to the rigid 1,3-diazaphenoxazine-2-one scaffold ($R_{10} = O$, $R_{11} = -O-(CH_2)_2-NH_2$, $R_{12-14} = H$) [Lin, K.-Y.; Matteucci, M. J. Am. Chem. Soc. 1998, 120, 8531-8532]. Binding studies demonstrated that a single incorporation could enhance the binding affinity of a model oligonucleotide to its complementary target DNA or RNA with a ΔT_m of up to 18° relative to 5-methyl cytosine (dC5^{me}), which is the highest known affinity enhancement for a single modification, yet. On the other hand, the gain in helical stability does not compromise the specificity of the oligonucleotides. The T_m data indicate an even greater discrimination between the perfect match and mismatched sequences compared to dC5^{me}. It was suggested that the tethered amino group serves as an additional hydrogen bond donor to interact with the Hoogsteen face, namely the O6, of a complementary guanine thereby forming 4 hydrogen bonds. This means that the increased affinity of G-clamp is mediated by the combination of extended base stacking and additional specific hydrogen bonding.

Further tricyclic heterocyclic compounds and methods of using them that are amenable to the present invention are disclosed in United States Patent Serial Number 6,028,183, which issued on May 22, 2000, and United States Patent Serial Number 6,007,992, which issued on December 28, 1999, the contents of both are commonly assigned with

this application and are incorporated herein in their entirety.

The enhanced binding affinity of the phenoxazine derivatives together with their uncompromised sequence specificity makes them valuable nucleobase analogs for the development of more potent antisense-based drugs. In fact, promising data have been derived from in vitro experiments demonstrating that heptanucleotides containing phenoxazine substitutions are capable to activate RNaseH, enhance cellular uptake and exhibit an increased antisense activity [Lin, K-Y; Matteucci, M. J. Am. Chem. Soc. 1998, 120, 8531-8532]. The activity enhancement was even more pronounced in case of G-clamp, as a single substitution was shown to significantly improve the in vitro potency of a 20mer 2'-deoxyphosphorothioate oligonucleotides [Flanagan, W. M.; Wolf, J.J.; Olson, P.; Grant, D.; Lin, K.-Y.; Wagner, R. W.; Matteucci, M. Proc. Natl. Acad. Sci. USA, 1999, 96, 3513-3518]. Nevertheless, to optimize oligonucleotide design and to better understand the impact of these heterocyclic modifications on the biological activity, it is important to evaluate their effect on the nuclease stability of the oligomers.

Further modified polycyclic heterocyclic compounds useful as heterocyclic bases are disclosed in but not limited to, the above noted U.S. 3,687,808, as well as U.S.: 4,845,205; 5,130,302; 5,134,066; 5,175,273; 5,367,066; 5,432,272; 5,434,257; 5,457,187; 5,459,255; 5,484,908; 5,502,177; 5,525,711; 5,552,540; 5,587,469; 5,594,121; 5,596,091; 5,614,617; 5,645,985; 5,646,269; 5,750,692; 5,830,653; 5,763,588; 6,005,096; and 5,681,941, and United States Patent Application Serial number 09/996,292 filed November 28, 2001, certain of which are commonly owned with the instant application, and each of which is herein incorporated by reference.

The oligonucleotides of the present invention also include variants in which a different base is present at one or more of the nucleotide positions in the

oligonucleotide. For example, if the first nucleotide is an adenosine, variants may be produced which contain thymidine, guanosine or cytidine at this position. This may be done at any of the positions of the oligonucleotide.

5 Thus, a 20-mer may comprise 60 variations (20 positions x 3 alternates at each position) in which the original nucleotide is substituted with any of the three alternate nucleotides. These oligonucleotides are then tested using the methods described herein to determine their ability to

10 inhibit expression of HCV mRNA and/or HCV replication.

Conjugates

A further preferred substitution that can be appended to the oligomeric compounds of the invention involves the

15 linkage of one or more moieties or conjugates which enhance the activity, cellular distribution or cellular uptake of the resulting oligomeric compounds. In one embodiment such modified oligomeric compounds are prepared by covalently attaching conjugate groups to functional groups such as

20 hydroxyl or amino groups. Conjugate groups of the invention include intercalators, reporter molecules, polyamines, polyamides, polyethylene glycols, polyethers, groups that enhance the pharmacodynamic properties of oligomers, and groups that enhance the pharmacokinetic

25 properties of oligomers. Typical conjugates groups include cholesterol, lipids, phospholipids, biotin, phenazine, folate, phenanthridine, anthraquinone, acridine, fluoresceins, rhodamines, coumarins, and dyes. Groups that enhance the pharmacodynamic properties, in the context of

30 this invention, include groups that improve oligomer uptake, enhance oligomer resistance to degradation, and/or strengthen sequence-specific hybridization with RNA. Groups that enhance the pharmacokinetic properties, in the context of this invention, include groups that improve

35 oligomer uptake, distribution, metabolism or excretion. Representative conjugate groups are disclosed in International Patent Application PCT/US92/09196, filed

October 23, 1992 the entire disclosure of which is incorporated herein by reference. Conjugate moieties include but are not limited to lipid moieties such as a cholesterol moiety (Letsinger et al., *Proc. Natl. Acad. Sci. USA*, **1989**,
5 86, 6553-6556), cholic acid (Manoharan et al., *Bioorg. Med. Chem. Lett.*, **1994**, 4, 1053-1060), a thioether, e.g., hexyl-S-tritylthiol (Manoharan et al., *Ann. N.Y. Acad. Sci.*, **1992**, 660, 306-309; Manoharan et al., *Bioorg. Med. Chem. Lett.*, **1993**, 3, 2765-2770), a thiocholesterol (Oberhauser et
10 al., *Nucl. Acids Res.*, **1992**, 20, 533-538), an aliphatic chain, e.g., dodecandiol or undecyl residues (Saison-Behmoaras et al., *EMBO J.*, **1991**, 10, 1111-1118; Kabanov et al., *FEBS Lett.*, **1990**, 259, 327-330; Svinarchuk et al., *Biochimie*, **1993**, 75, 49-54), a phospholipid, e.g., di-
15 hexadecyl-rac-glycerol or triethylammonium 1,2-di-O-hexadecyl-rac-glycero-3-H-phosphonate (Manoharan et al., *Tetrahedron Lett.*, **1995**, 36, 3651-3654; Shea et al., *Nucl. Acids Res.*, **1990**, 18, 3777-3783), a polyamine or a polyethylene glycol chain (Manoharan et al., *Nucleosides &*
20 *Nucleotides*, **1995**, 14, 969-973), or adamantane acetic acid (Manoharan et al., *Tetrahedron Lett.*, **1995**, 36, 3651-3654), a palmityl moiety (Mishra et al., *Biochim. Biophys. Acta*, **1995**, 1264, 229-237), or an octadecylamine or hexylamino-carbonyl-oxycholesterol moiety (Crooke et al., *J.*
25 *Pharmacol. Exp. Ther.*, **1996**, 277, 923-937).

The oligomeric compounds of the invention may also be conjugated to active drug substances, for example, aspirin, warfarin, phenylbutazone, ibuprofen, suprofen, fenbufen, ketoprofen, (S)-(+)-pranoprofen, carprofen,
30 dansylsarcosine, 2,3,5-triiodobenzoic acid, flufenamic acid, folinic acid, a benzothiadiazide, chlorothiazide, a diazepine, indomethicin, a barbiturate, a cephalosporin, a sulfa drug, an antidiabetic, an antibacterial or an

antibiotic. Oligonucleotide-drug conjugates and their preparation are described in United States Patent Application 09/334,130 (filed June 15, 1999) which is incorporated herein by reference in its entirety.

5 Representative United States patents that teach the preparation of such oligonucleotide conjugates include, but are not limited to, U.S.: 4,828,979; 4,948,882; 5,218,105; 5,525,465; 5,541,313; 5,545,730; 5,552,538; 5,578,717; 5,580,731; 5,580,731; 5,591,584; 5,109,124; 5,118,802;
10 5,138,045; 5,414,077; 5,486,603; 5,512,439; 5,578,718; 5,608,046; 4,587,044; 4,605,735; 4,667,025; 4,762,779; 4,789,737; 4,824,941; 4,835,263; 4,876,335; 4,904,582; 4,958,013; 5,082,830; 5,112,963; 5,214,136; 5,082,830; 5,112,963; 5,214,136; 5,245,022; 5,254,469; 5,258,506;
15 5,262,536; 5,272,250; 5,292,873; 5,317,098; 5,371,241; 5,391,723; 5,416,203; 5,451,463; 5,510,475; 5,512,667; 5,514,785; 5,565,552; 5,567,810; 5,574,142; 5,585,481; 5,587,371; 5,595,726; 5,597,696; 5,599,923; 5,599,928 and 5,688,941, certain of which are commonly owned with the
20 instant application, and each of which is herein incorporated by reference.

Chimeric oligomeric compounds

It is not necessary for all positions in an oligomeric
25 compound to be uniformly modified, and in fact more than one of the aforementioned modifications may be incorporated in a single oligomeric compound or even at a single monomeric subunit such as a nucleoside within a oligomeric compound. The present invention also includes oligomeric
30 compounds which are chimeric oligomeric compounds. "Chimeric" oligomeric compounds or "chimeras," in the context of this invention, are oligomeric compounds that contain two or more chemically distinct regions, each made up of at least one monomer unit, i.e., a nucleotide in the
35 case of a nucleic acid based oligomer.

Chimeric oligomeric compounds typically contain at least one region modified so as to confer increased

resistance to nuclease degradation, increased cellular uptake, and/or increased binding affinity for the target nucleic acid. An additional region of the oligomeric compound may serve as a substrate for enzymes capable of cleaving RNA:DNA or RNA:RNA hybrids. By way of example, RNase H is a cellular endonuclease which cleaves the RNA strand of an RNA:DNA duplex. Activation of RNase H, therefore, results in cleavage of the RNA target, thereby greatly enhancing the efficiency of inhibition of gene expression. Consequently, comparable results can often be obtained with shorter oligomeric compounds when chimeras are used, compared to for example phosphorothioate deoxyoligonucleotides hybridizing to the same target region. Cleavage of the RNA target can be routinely detected by gel electrophoresis and, if necessary, associated nucleic acid hybridization techniques known in the art.

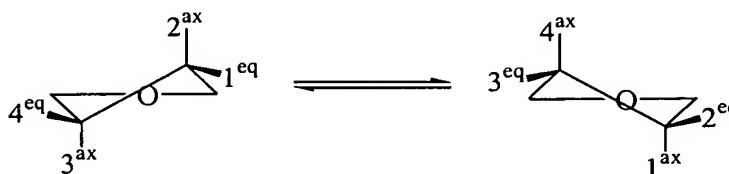
Chimeric oligomeric compounds of the invention may be formed as composite structures of two or more oligonucleotides, oligonucleotide analogs, oligonucleosides and/or oligonucleotide mimetics as described above. Such oligomeric compounds have also been referred to in the art as hybrids hemimers, gapmers or inverted gapmers. Representative United States patents that teach the preparation of such hybrid structures include, but are not limited to, U.S.: 5,013,830; 5,149,797; 5,220,007; 5,256,775; 5,366,878; 5,403,711; 5,491,133; 5,565,350; 5,623,065; 5,652,355; 5,652,356; and 5,700,922, certain of which are commonly owned with the instant application, and each of which is herein incorporated by reference in its entirety.

3'-endo modifications

In one aspect of the present invention oligomeric compounds include nucleosides synthetically modified to induce a 3'-endo sugar conformation. A nucleoside can incorporate synthetic modifications of the heterocyclic

base, the sugar moiety or both to induce a desired 3'-endo sugar conformation. These modified nucleosides are used to mimic RNA like nucleosides so that particular properties of an oligomeric compound can be enhanced while maintaining the desirable 3'-endo conformational geometry. There is an apparent preference for an RNA type duplex (A form helix, predominantly 3'-endo) as a requirement (e.g. trigger) of RNA interference which is supported in part by the fact that duplexes composed of 2'-deoxy-2'-F-nucleosides appears efficient in triggering RNAi response in the *C. elegans* system. Properties that are enhanced by using more stable 3'-endo nucleosides include but aren't limited to modulation of pharmacokinetic properties through modification of protein binding, protein off-rate, absorption and clearance; modulation of nuclease stability as well as chemical stability; modulation of the binding affinity and specificity of the oligomer (affinity and specificity for enzymes as well as for complementary sequences); and increasing efficacy of RNA cleavage. The present invention provides oligomeric triggers of RNAi having one or more nucleosides modified in such a way as to favor a C3'-endo type conformation.

Scheme 1

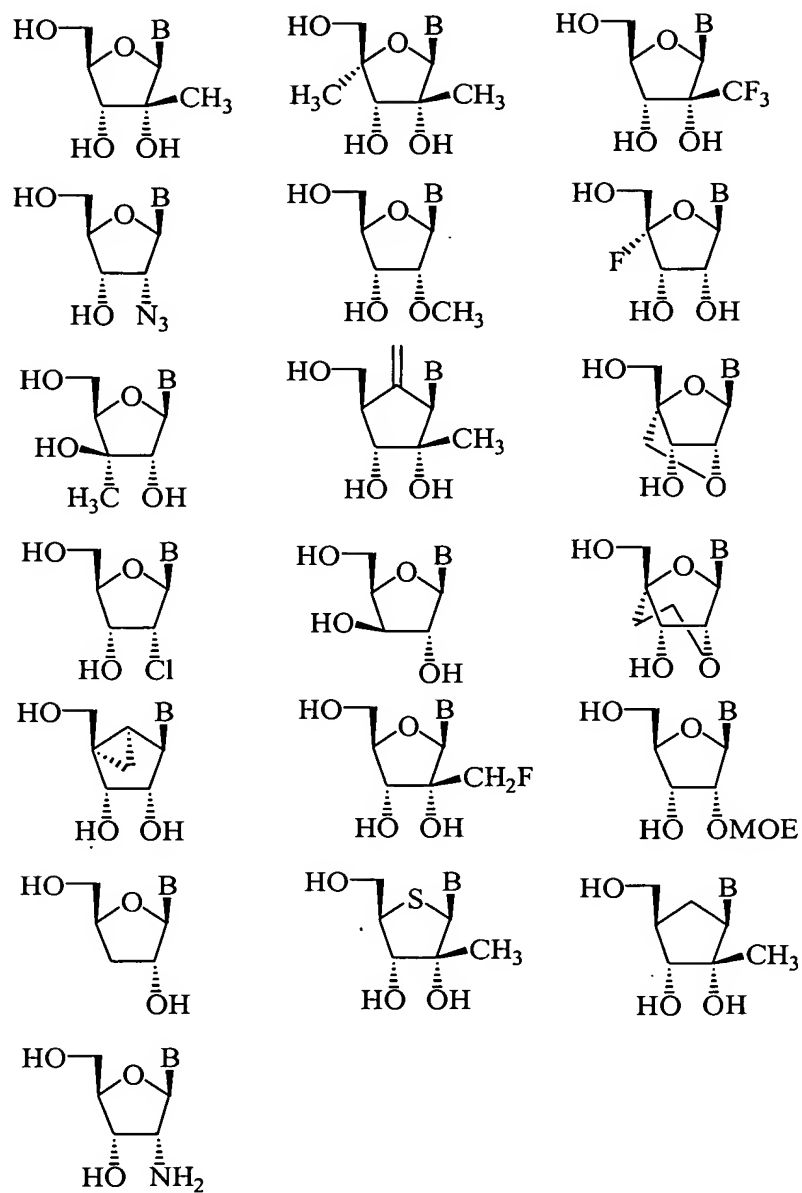


C2'-endo/Southern C3'-endo/Northern

Nucleoside conformation is influenced by various factors including substitution at the 2', 3' or 4'-positions of the pentofuranosyl sugar. Electronegative substituents generally prefer the axial positions, while sterically demanding substituents generally prefer the equatorial positions (Principles of Nucleic Acid Structure, Wolfgang Sanger, 1984, Springer-Verlag.) Modification of

the 2' position to favor the 3'-endo conformation can be achieved while maintaining the 2'-OH as a recognition element, as illustrated in Figure 2, below (Gallo et al., Tetrahedron (2001), 57, 5707-5713. Harry-O'kuru et al., J. Org. Chem., (1997), 62(6), 1754-1759 and Tang et al., J. Org. Chem. (1999), 64, 747-754.) Alternatively, preference for the 3'-endo conformation can be achieved by deletion of the 2'-OH as exemplified by 2'-deoxy-2'-F-nucleosides (Kawasaki et al., J. Med. Chem. (1993), 36, 831-841), which adopts the 3'-endo conformation positioning the electronegative fluorine atom in the axial position. Other modifications of the ribose ring, for example substitution at the 4'-position to give 4'-F modified nucleosides (Guillerm et al., Bioorganic and Medicinal Chemistry Letters (1995), 5, 1455-1460 and Owen et al., J. Org. Chem. (1976), 41, 3010-3017), or for example modification to yield methanocarpa nucleoside analogs (Jacobson et al., J. Med. Chem. Lett. (2000), 43, 2196-2203 and Lee et al., Bioorganic and Medicinal Chemistry Letters (2001), 11, 1333-1337) also induce preference for the 3'-endo conformation. Along similar lines, oligomeric triggers of RNAi response might be composed of one or more nucleosides modified in such a way that conformation is locked into a C3'-endo type conformation, i.e. Locked Nucleic Acid (LNA, Singh et al, Chem. Commun. (1998), 4, 455-456), and ethylene bridged Nucleic Acids (ENA, Morita et al, Bioorganic & Medicinal Chemistry Letters (2002), 12, 73-76.) Examples of modified nucleosides amenable to the present invention are shown below in Table I. These examples are meant to be representative and not exhaustive.

Table I



- 5 The preferred conformation of modified nucleosides and their oligomers can be estimated by various methods such as molecular dynamics calculations, nuclear magnetic resonance spectroscopy and CD measurements. Hence, modifications predicted to induce RNA like conformations, A-form duplex

geometry in an oligomeric context, are selected for use in the modified oligonucleotides of the present invention. The synthesis of numerous of the modified nucleosides amenable to the present invention are known in the art (see for example, Chemistry of Nucleosides and Nucleotides Vol 1-3, ed. Leroy B. Townsend, 1988, Plenum press., and the examples section below.) Nucleosides known to be inhibitors/substrates for RNA dependent RNA polymerases (for example HCV NS5B

10 In one aspect, the present invention is directed to oligonucleotides that are prepared having enhanced properties compared to native RNA against nucleic acid targets. A target is identified and an oligonucleotide is selected having an effective length and sequence that is
15 complementary to a portion of the target sequence. Each nucleoside of the selected sequence is scrutinized for possible enhancing modifications. A preferred modification would be the replacement of one or more RNA nucleosides with nucleosides that have the same 3'-endo conformational
20 geometry. Such modifications can enhance chemical and nuclease stability relative to native RNA while at the same time being much cheaper and easier to synthesize and/or incorporate into an oligonucleotide. The selected sequence can be further divided into regions and the nucleosides of
25 each region evaluated for enhancing modifications that can be the result of a chimeric configuration. Consideration is also given to the 5' and 3'-termini as there are often advantageous modifications that can be made to one or more of the terminal nucleosides. The oligomeric compounds of
30 the present invention include at least one 5'-modified phosphate group on a single strand or on at least one 5'-position of a double stranded sequence or sequences. Further modifications are also considered such as
35 internucleoside linkages, conjugate groups, substitute sugars or bases, substitution of one or more nucleosides with nucleoside mimetics and any other modification that can enhance the selected sequence for its intended target.

The terms used to describe the conformational geometry of homoduplex nucleic acids are "A Form" for RNA and "B Form" for DNA. The respective conformational geometry for RNA and DNA duplexes was determined from X-ray diffraction analysis of nucleic acid fibers (Arnott and Hukins, *Biochem. Biophys. Res. Comm.*, 1970, 47, 1504.) In general, RNA:RNA duplexes are more stable and have higher melting temperatures (T_m 's) than DNA:DNA duplexes (Sanger et al., *Principles of Nucleic Acid Structure*, 1984, Springer-Verlag; New York, NY.; Lesnik et al., *Biochemistry*, 1995, 34, 10807-10815; Conte et al., *Nucleic Acids Res.*, 1997, 25, 2627-2634). The increased stability of RNA has been attributed to several structural features, most notably the improved base stacking interactions that result from an A-form geometry (Searle et al., *Nucleic Acids Res.*, 1993, 21, 2051-2056). The presence of the 2' hydroxyl in RNA biases the sugar toward a C3' endo pucker, i.e., also designated as Northern pucker, which causes the duplex to favor the A-form geometry. In addition, the 2' hydroxyl groups of RNA can form a network of water mediated hydrogen bonds that help stabilize the RNA duplex (Egli et al., *Biochemistry*, 1996, 35, 8489-8494). On the other hand, deoxy nucleic acids prefer a C2' endo sugar pucker, i.e., also known as Southern pucker, which is thought to impart a less stable B-form geometry (Sanger, W. (1984) *Principles of Nucleic Acid Structure*, Springer-Verlag, New York, NY). As used herein, B-form geometry is inclusive of both C2'-endo pucker and O4'-endo pucker. This is consistent with Berger, et. al., *Nucleic Acids Research*, 1998, 26, 2473-2480, who pointed out that in considering the furanose conformations which give rise to B-form duplexes consideration should also be given to a O4'-endo pucker contribution.

DNA:RNA hybrid duplexes, however, are usually less stable than pure RNA:RNA duplexes, and depending on their sequence may be either more or less stable than DNA:DNA duplexes (Searle et al., *Nucleic Acids Res.*, 1993, 21,

2051-2056). The structure of a hybrid duplex is intermediate between A- and B-form geometries, which may result in poor stacking interactions (Lane et al., *Eur. J. Biochem.*, 1993, 215, 297-306; Fedoroff et al., *J. Mol.*

5 *Biol.*, 1993, 233, 509-523; Gonzalez et al., *Biochemistry*, 1995, 34, 4969-4982; Horton et al., *J. Mol. Biol.*, 1996, 264, 521-533). The stability of the duplex formed between a target RNA and a synthetic sequence is central to therapies such as but not limited to antisense and RNA
10 interference as these mechanisms require the binding of a synthetic oligonucleotide strand to an RNA target strand. In the case of antisense, effective inhibition of the mRNA requires that the antisense DNA have a very high binding affinity with the mRNA. Otherwise the desired interaction
15 between the synthetic oligonucleotide strand and target mRNA strand will occur infrequently, resulting in decreased efficacy.

One routinely used method of modifying the sugar puckering is the substitution of the sugar at the 2'-
20 position with a substituent group that influences the sugar geometry. The influence on ring conformation is dependant on the nature of the substituent at the 2'-position. A number of different substituents have been studied to determine their sugar puckering effect. For example, 2'-
25 halogens have been studied showing that the 2'-fluoro derivative exhibits the largest population (65%) of the C3'-endo form, and the 2'-iodo exhibits the lowest population (7%). The populations of adenosine (2'-OH) versus deoxyadenosine (2'-H) are 36% and 19%, respectively.
30 Furthermore, the effect of the 2'-fluoro group of adenosine dimers (2'-deoxy-2'-fluoroadenosine - 2'-deoxy-2'-fluoro-adenosine) is further correlated to the stabilization of the stacked conformation.

As expected, the relative duplex stability can be
35 enhanced by replacement of 2'-OH groups with 2'-F groups thereby increasing the C3'-endo population. It is assumed

that the highly polar nature of the 2'-F bond and the extreme preference for C3'-endo puckering may stabilize the stacked conformation in an A-form duplex. Data from UV hypochromicity, circular dichroism, and ¹H NMR also indicate
5 that the degree of stacking decreases as the electronegativity of the halo substituent decreases.

Furthermore, steric bulk at the 2'-position of the sugar moiety is better accommodated in an A-form duplex than a B-form duplex. Thus, a 2'-substituent on the 3'-terminus of
10 a dinucleoside monophosphate is thought to exert a number of effects on the stacking conformation: steric repulsion, furanose puckering preference, electrostatic repulsion, hydrophobic attraction, and hydrogen bonding capabilities.

These substituent effects are thought to be determined by
15 the molecular size, electronegativity, and hydrophobicity of the substituent. Melting temperatures of complementary strands is also increased with the 2'-substituted adenosine diphosphates. It is not clear whether the 3'-endo preference of the conformation or the presence of the
20 substituent is responsible for the increased binding. However, greater overlap of adjacent bases (stacking) can be achieved with the 3'-endo conformation.

One synthetic 2'-modification that imparts increased nuclease resistance and a very high binding affinity to
25 nucleotides is the 2-methoxyethoxy (2'-MOE, 2'-OCH₂CH₂OCH₃) side chain (Baker et al., *J. Biol. Chem.*, 1997, 272, 11944-12000). One of the immediate advantages of the 2'-MOE substitution is the improvement in binding affinity, which is greater than many similar 2' modifications such as O-
30 methyl, O-propyl, and O-aminopropyl. Oligonucleotides having the 2'-O-methoxyethyl substituent also have been shown to be antisense inhibitors of gene expression with promising features for *in vivo* use (Martin, P., *Helv. Chim. Acta*, 1995, 78, 486-504; Altmann et al., *Chimia*, 1996, 50,
35 168-176; Altmann et al., *Biochem. Soc. Trans.*, 1996, 24, 630-637; and Altmann et al., *Nucleosides Nucleotides*, 1997,

16, 917-926). Relative to DNA, the oligonucleotides having the 2'-MOE modification displayed improved RNA affinity and higher nuclease resistance. Chimeric oligonucleotides having 2'-MOE substituents in the wing nucleosides and an internal region of deoxy-phosphorothioate nucleotides (also termed a gapped oligonucleotide or gapmer) have shown effective reduction in the growth of tumors in animal models at low doses. 2'-MOE substituted oligonucleotides have also shown outstanding promise as antisense agents in several disease states. One such MOE substituted oligonucleotide is presently being investigated in clinical trials for the treatment of CMV retinitis.

Chemistries Defined

15 Unless otherwise defined herein, alkyl means C₁-C₁₂, preferably C₁-C₈, and more preferably C₁-C₆, straight or (where possible) branched chain aliphatic hydrocarbyl.

Unless otherwise defined herein, heteroalkyl means C₁-C₁₂, preferably C₁-C₈, and more preferably C₁-C₆, straight or (where possible) branched chain aliphatic hydrocarbyl containing at least one, and preferably about 1 to about 3, hetero atoms in the chain, including the terminal portion of the chain. Preferred heteroatoms include N, O and S.

25 Unless otherwise defined herein, cycloalkyl means C₃-C₁₂, preferably C₃-C₈, and more preferably C₃-C₆, aliphatic hydrocarbyl ring.

30 Unless otherwise defined herein, alkenyl means C₂-C₁₂, preferably C₂-C₈, and more preferably C₂-C₆ alkenyl, which may be straight or (where possible) branched hydrocarbyl moiety, which contains at least one carbon-carbon double bond.

35 Unless otherwise defined herein, alkynyl means C₂-C₁₂, preferably C₂-C₈, and more preferably C₂-C₆ alkynyl, which may be straight or (where possible) branched hydrocarbyl moiety, which contains at least one carbon-carbon triple bond.

Unless otherwise defined herein, heterocycloalkyl means a ring moiety containing at least three ring members, at least one of which is carbon, and of which 1, 2 or three ring members are other than carbon. Preferably the number
5 of carbon atoms varies from 1 to about 12, preferably 1 to about 6, and the total number of ring members varies from three to about 15, preferably from about 3 to about 8. Preferred ring heteroatoms are N, O and S. Preferred heterocycloalkyl groups include morpholino, thiomorpholino,
10 piperidinyl, piperazinyl, homopiperidinyl, homopiperazinyl, homomorpholino, homothiomorpholino, pyrrolodinyl, tetrahydrooxazolyl, tetrahydroimidazolyl, tetrahydrothiazolyl, tetrahydroisoxazolyl, tetrahydropyrrazolyl, furanyl, pyranal, and
15 tetrahydroisothiazolyl.

Unless otherwise defined herein, aryl means any hydrocarbon ring structure containing at least one aryl ring. Preferred aryl rings have about 6 to about 20 ring carbons. Especially preferred aryl rings include phenyl,
20 naphthyl, anthracenyl, and phenanthrenyl.

Unless otherwise defined herein, hetaryl means a ring moiety containing at least one fully unsaturated ring, the ring consisting of carbon and non-carbon atoms. Preferably the ring system contains about 1 to about 4 rings.
25 Preferably the number of carbon atoms varies from 1 to about 12, preferably 1 to about 6, and the total number of ring members varies from three to about 15, preferably from about 3 to about 8. Preferred ring heteroatoms are N, O and S. Preferred hetaryl moieties include pyrazolyl, thiophenyl, pyridyl, imidazolyl, tetrazolyl, pyridyl,
30 pyrimidinyl, purinyl, quinazolinyl, quinoxalinyl, benzimidazolyl, benzothiophenyl, etc.

Unless otherwise defined herein, where a moiety is defined as a compound moiety, such as hetarylalkyl (hetaryl
35 and alkyl), aralkyl (aryl and alkyl), etc., each of the sub-moieties is as defined herein.

Unless otherwise defined herein, an electron withdrawing group is a group, such as the cyano or isocyanato group that draws electronic charge away from the carbon to which it is attached. Other electron withdrawing groups of note include those whose electronegativities exceed that of carbon, for example halogen, nitro, or phenyl substituted in the ortho- or para-position with one or more cyano, isothiocyanato, nitro or halo groups.

Unless otherwise defined herein, the terms halogen and halo have their ordinary meanings. Preferred halo (halogen) substituents are Cl, Br, and I. The aforementioned optional substituents are, unless otherwise herein defined, suitable substituents depending upon desired properties. Included are halogens (Cl, Br, I), alkyl, alkenyl, and alkynyl moieties, NO₂, NH₂ (substituted and unsubstituted), acid moieties (e.g. -CO₂H, -OSO₃H₂, etc.), heterocycloalkyl moieties, hetaryl moieties, aryl moieties, etc.

In all the preceding formulae, the squiggle (~) indicates a bond to an oxygen or sulfur of the 5'-phosphate.

Phosphate protecting groups include those described in US Patents No. US 5,760,209, US 5,614,621, US 6,051,699, US 6,020,475, US 6,326,478, US 6,169,177, US 6,121,437, US 6,465,628 each of which is expressly incorporated herein by reference in its entirety.

The oligonucleotides in accordance with this invention (single stranded or double stranded) preferably comprise from about 8 to about 80 nucleotides, more preferably from about 12-50 nucleotides and most preferably from about 15 to 30 nucleotides. As is known in the art, a nucleotide is a base-sugar combination suitably bound to an adjacent nucleotide through a phosphodiester, phosphorothioate or other covalent linkage.

The oligonucleotides of the present invention also include variants in which a different base is present at one or more of the nucleotide positions in the oligonucleotide. For example, if the first nucleotide is an

adenosine, variants may be produced which contain thymidine, guanosine or cytidine at this position. This may be done at any of the positions of the oligonucleotide.

Thus, a 20-mer may comprise 60 variations (20 positions x 3 alternates at each position) in which the original nucleotide is substituted with any of the three alternate nucleotides. These oligonucleotides are then tested using the methods described herein to determine their ability to inhibit expression of STAT3 mRNA.

10 The oligonucleotides used in accordance with this invention may be conveniently and routinely made through the well-known technique of solid phase synthesis. Equipment for such synthesis is sold by several vendors including Applied Biosystems. Any other means for such
15 synthesis may also be employed; the actual synthesis of the oligonucleotides is well within the talents of the routineer. It is well known to use similar techniques to prepare oligonucleotides such as the phosphorothioates and 2'-alkoxy or 2'-alkoxyalkoxy derivatives, including 2'-O-
20 methoxyethyl oligonucleotides (Martin, P., *Helv. Chim. Acta* 1995, 78, 486-504). It is also well known to use similar techniques and commercially available modified amidites and controlled-pore glass (CPG) products such as biotin, fluorescein, acridine or psoralen-modified amidites and/or
25 CPG (available from Glen Research, Sterling, VA) to synthesize fluorescently labeled, biotinylated or other conjugated oligonucleotides.

 The antisense compounds of the present invention include bioequivalent compounds, including pharmaceutically
30 acceptable salts and prodrugs. This is intended to encompass any pharmaceutically acceptable salts, esters, or salts of such esters, or any other compound which, upon administration to an animal including a human, is capable of providing (directly or indirectly) the biologically
35 active metabolite or residue thereof. Accordingly, for example, the disclosure is also drawn to pharmaceutically acceptable salts of the nucleic acids of the invention and

prodrugs of such nucleic acids. AP harmaceutically acceptable salts@ are physiologically and pharmaceutically acceptable salts of the nucleic acids of the invention: i.e., salts that retain the desired biological activity of the parent compound and do not impart undesired toxicological effects thereto (see, for example, Berge et al., "Pharmaceutical Salts," *J. of Pharma Sci.* 1977, 66, 1-19).

For oligonucleotides, examples of pharmaceutically acceptable salts include but are not limited to (a) salts formed with cations such as sodium, potassium, ammonium, magnesium, calcium, polyamines such as spermine and spermidine, etc.; (b) acid addition salts formed with inorganic acids, for example hydrochloric acid, hydrobromic acid, sulfuric acid, phosphoric acid, nitric acid and the like; (c) salts formed with organic acids such as, for example, acetic acid, oxalic acid, tartaric acid, succinic acid, maleic acid, fumaric acid, gluconic acid, citric acid, malic acid, ascorbic acid, benzoic acid, tannic acid, palmitic acid, alginic acid, polyglutamic acid, naphthalenesulfonic acid, methanesulfonic acid, p-toluenesulfonic acid, naphthalenedisulfonic acid, polygalacturonic acid, and the like; and (d) salts formed from elemental anions such as chlorine, bromine, and iodine.

The oligonucleotides of the invention may additionally or alternatively be prepared to be delivered in a A prodrug@ form. The term A prodrug@ indicates a therapeutic agent that is prepared in an inactive form that is converted to an active form (i.e., drug) within the body or cells thereof by the action of endogenous enzymes or other chemicals and/or conditions. In particular, prodrug versions of the oligonucleotides of the invention are prepared as SATE [(S-acetyl-2-thioethyl) phosphate] derivatives according to the methods disclosed in WO 93/24510 to Gosselin et al., published December 9, 1993.

For therapeutic or prophylactic treatment, oligonucleotides are administered in accordance with this invention. Oligonucleotide compounds of the invention may be formulated in a pharmaceutical composition, which may include pharmaceutically acceptable carriers, thickeners, diluents, buffers, preservatives, surface active agents, neutral or cationic lipids, lipid complexes, liposomes, penetration enhancers, carrier compounds and other pharmaceutically acceptable carriers or excipients and the like in addition to the oligonucleotide. Such compositions and formulations are comprehended by the present invention.

Pharmaceutical compositions comprising the oligonucleotides of the present invention may include penetration enhancers in order to enhance the alimentary delivery of the oligonucleotides. Penetration enhancers may be classified as belonging to one of five broad categories, i.e., fatty acids, bile salts, chelating agents, surfactants and non-surfactants (Lee et al., *Critical Reviews in Therapeutic Drug Carrier Systems* 1991, 8, 91-192; Muranishi, *Critical Reviews in Therapeutic Drug Carrier Systems* 1990, 7, 1-33). One or more penetration enhancers from one or more of these broad categories may be included. Various fatty acids and their derivatives which act as penetration enhancers include, for example, oleic acid, lauric acid, capric acid, myristic acid, palmitic acid, stearic acid, linoleic acid, linolenic acid, dicaprate, tricaprate, recinleate, monoolein (a.k.a. 1-monooleoyl-rac-glycerol), dilaurin, caprylic acid, arachidonic acid, glyceryl 1-monocaprate, 1-dodecylazacycloheptan-2-one, acylcarnitines, acylcholines, mono- and di-glycerides and physiologically acceptable salts thereof (i.e., oleate, laurate, caprate, myristate, palmitate, stearate, linoleate, etc.) (Lee et al., *Critical Reviews in Therapeutic Drug Carrier Systems* 1991, page 92; Muranishi, *Critical Reviews in Therapeutic Drug Carrier*

Systems 1990, 7, 1; El-Hariri et al., *J. Pharm. Pharmacol.* 1992 44, 651-654).

The physiological roles of bile include the facilitation of dispersion and absorption of lipids and fat-soluble vitamins (Brunton, Chapter 38 In: Goodman & Gilman's *The Pharmacological Basis of Therapeutics*, 9th Ed., Hardman et al., eds., McGraw-Hill, New York, NY, 1996, pages 934-935). Various natural bile salts, and their synthetic derivatives, act as penetration enhancers. Thus, the term "bile salt" includes any of the naturally occurring components of bile as well as any of their synthetic derivatives.

Complex formulations comprising one or more penetration enhancers may be used. For example, bile salts may be used in combination with fatty acids to make complex formulations.

Chelating agents include, but are not limited to, disodium ethylenediaminetetraacetate (EDTA), citric acid, salicylates (e.g., sodium salicylate, 5-methoxysalicylate and homovanilate), *N*-acyl derivatives of collagen, laur eth-9 and *N*-amino acyl derivatives of beta-diketones (enamines) [Lee et al., *Critical Reviews in Therapeutic Drug Carrier Systems* 1991, page 92; Muranishi, *Critical Reviews in Therapeutic Drug Carrier Systems* 1990, 7, 1-33; Buur et al., *J. Control Rel.* 1990, 14, 43-51). Chelating agents have the added advantage of also serving as DNase inhibitors.

Surfactants include, for example, sodium lauryl sulfate, polyoxyethylene-9-lauryl ether and polyoxyethylene-20-cetyl ether (Lee et al., *Critical Reviews in Therapeutic Drug Carrier Systems* 1991, page 92); and perfluorochemical emulsions, such as FC-43 (Takahashi et al., *J. Pharm. Pharmacol.* 1988, 40, 252-257).

Non-surfactants include, for example, unsaturated cyclic ureas, 1-alkyl- and 1-alkenylazacyclo-alkanone derivatives (Lee et al., *Critical Reviews in Therapeutic Drug Carrier Systems* 1991, page 92); and non-steroidal
5 anti-inflammatory agents such as diclofenac sodium, indomethacin and phenylbutazone (Yamashita et al., *J. Pharm. Pharmacol.* 1987, 39, 621-626).

As used herein, "carrier compound" refers to a nucleic acid, or analog thereof, which is inert (i.e., does
10 not possess biological activity per se) but is recognized as a nucleic acid by *in vivo* processes that reduce the bioavailability of a nucleic acid having biological activity by, for example, degrading the biologically active nucleic acid or promoting its removal from circulation.
15 The coadministration of a nucleic acid and a carrier compound, typically with an excess of the latter substance, can result in a substantial reduction of the amount of nucleic acid recovered in the liver, kidney or other extracirculatory reservoirs, presumably due to competition
20 between the carrier compound and the nucleic acid for a common receptor. In contrast to a carrier compound, a "pharmaceutically acceptable carrier" (excipient) is a pharmaceutically acceptable solvent, suspending agent or any other pharmacologically inert vehicle for delivering
25 one or more nucleic acids to an animal. The pharmaceutically acceptable carrier may be liquid or solid and is selected with the planned manner of administration in mind so as to provide for the desired bulk, consistency, etc., when combined with a nucleic acid and the other
30 components of a given pharmaceutical composition. Typical pharmaceutically acceptable carriers include, but are not limited to, binding agents (e.g., pregelatinized maize starch, polyvinylpyrrolidone or hydroxypropyl methylcellulose, etc.); fillers (e.g., lactose and other
35 sugars, microcrystalline cellulose, pectin, gelatin,

calcium sulfate, ethyl cellulose, polyacrylates or calcium hydrogen phosphate, etc.); lubricants (e.g., magnesium stearate, talc, silica, colloidal silicon dioxide, stearic acid, metallic stearates, hydrogenated vegetable oils, corn starch, polyethylene glycols, sodium benzoate, sodium acetate, etc.); disintegrates (e.g., starch, sodium starch glycolate, etc.); or wetting agents (e.g., sodium lauryl sulphate, etc.). Sustained release oral delivery systems and/or enteric coatings for orally administered dosage forms are described in U.S. Patents Nos. 4,704,295; 4,556,552; 4,309,406; and 4,309,404.

The compositions of the present invention may additionally contain other adjunct components conventionally found in pharmaceutical compositions, at their art-established usage levels. Thus, for example, the compositions may contain additional compatible pharmaceutically-active materials such as, e.g., antipruritics, astringents, local anesthetics or anti-inflammatory agents, or may contain additional materials useful in physically formulating various dosage forms of the composition of present invention, such as dyes, flavoring agents, preservatives, antioxidants, opacifiers, thickening agents and stabilizers. However, such materials, when added, should not unduly interfere with the biological activities of the components of the compositions of the invention.

Regardless of the method by which the oligonucleotides of the invention are introduced into a patient, colloidal dispersion systems may be used as delivery vehicles to enhance the *in vivo* stability of the oligonucleotides and/or to target the oligonucleotides to a particular organ, tissue or cell type. Colloidal dispersion systems include, but are not limited to, macromolecule complexes, nanocapsules, microspheres, beads and lipid-based systems including oil-in-water emulsions, micelles, mixed micelles, liposomes and

lipid:oligonucleotide complexes of uncharacterized structure. A preferred colloidal dispersion system is a plurality of liposomes. Liposomes are microscopic spheres having an aqueous core surrounded by one or more outer
5 layers made up of lipids arranged in a bilayer configuration (see, generally, Chonn et al., *Current Op. Biotech.* 1995, 6, 698-708).

The pharmaceutical compositions of the present invention may be administered in a number of ways depending
10 upon whether local or systemic treatment is desired and upon the area to be treated. Administration may be topical (including ophthalmic, vaginal, rectal, intranasal, epidermal, and transdermal), oral or parenteral. Parenteral administration includes intravenous drip,
15 subcutaneous, intraperitoneal or intramuscular injection, pulmonary administration, e.g., by inhalation or insufflation, or intracranial, e.g., intrathecal or intraventricular, administration. Oligonucleotides with at least one 2'-O-methoxyethyl modification are believed to be
20 particularly useful for oral administration.

Formulations for topical administration may include transdermal patches, ointments, lotions, creams, gels, drops, suppositories, sprays, liquids and powders. Conventional pharmaceutical carriers, aqueous, powder or
25 oily bases, thickeners and the like may be necessary or desirable. Coated condoms, gloves and the like may also be useful.

Compositions for oral administration include powders or granules, suspensions or solutions in water or non-
30 aqueous media, capsules, sachets or tablets. Thickeners, flavoring agents, diluents, emulsifiers, dispersing aids or binders may be desirable.

Compositions for parenteral administration may include sterile aqueous solutions which may also contain
35 buffers, diluents and other suitable additives. In some cases it may be more effective to treat a patient with an oligonucleotide of the invention in conjunction with other

traditional therapeutic modalities in order to increase the efficacy of a treatment regimen. In the context of the invention, the term "treatment regimen" is meant to encompass therapeutic, palliative and prophylactic modalities. For example, a patient may be treated with conventional chemotherapeutic agents, particularly those used for tumor and cancer treatment. Examples of such chemotherapeutic agents include but are not limited to daunorubicin, daunomycin, dactinomycin, doxorubicin, epirubicin, idarubicin, esorubicin, bleomycin, mafosfamide, ifosfamide, cytosine arabinoside, bis-chloroethylnitrosurea, busulfan, mitomycin C, actinomycin D, mithramycin, prednisone, hydroxyprogesterone, testosterone, tamoxifen, dacarbazine, procarbazine, hexamethylmelamine, pentamethylmelamine, mitoxantrone, amsacrine, chlorambucil, methylcyclohexylnitrosurea, nitrogen mustards, melphalan, cyclophosphamide, 6-mercaptapurine, 6-thioguanine, cytarabine (CA), 5-azacytidine, hydroxyurea, deoxycoformycin, 4-hydroxyperoxycyclophosphoramide, 5-fluorouracil (5-FU), 5-fluorodeoxyuridine (5-FUdR), methotrexate (MTX), colchicine, taxol, vincristine, vinblastine, etoposide, trimetrexate, teniposide, cisplatin, gemcitabine and diethylstilbestrol (DES). See, generally, *The Merck Manual of Diagnosis and Therapy*, 15th Ed. 1987, pp. 1206-1228, Berkow et al., eds., Rahway, N.J. When used with the compounds of the invention, such chemotherapeutic agents may be used individually (e.g., 5-FU and oligonucleotide), sequentially (e.g., 5-FU and oligonucleotide for a period of time followed by MTX and oligonucleotide), or in combination with one or more other such chemotherapeutic agents (e.g., 5-FU, MTX and oligonucleotide, or 5-FU, radiotherapy and oligonucleotide).

The formulation of therapeutic compositions and their subsequent administration is believed to be within the skill of those in the art. Dosing is dependent on severity

and responsiveness of the disease state to be treated, with the course of treatment lasting from several days to several months, or until a cure is effected or a diminution of the disease state is achieved. Optimal dosing schedules can be calculated from measurements of drug accumulation in the body of the patient. Persons of ordinary skill can easily determine optimum dosages, dosing methodologies and repetition rates. Optimum dosages may vary depending on the relative potency of individual oligonucleotides, and can generally be estimated based on EC_{50} s found to be effective *in vitro* and in *in vivo* animal models. In general, dosage is from 0.01 g to 100 g per kg of body weight, and may be given once or more daily, weekly, monthly or yearly, or even once every 2 to 20 years. Persons of ordinary skill in the art can easily estimate repetition rates for dosing based on measured residence times and concentrations of the drug in bodily fluids or tissues. Following successful treatment, it may be desirable to have the patient undergo maintenance therapy to prevent the recurrence of the disease state, wherein the oligonucleotide is administered in maintenance doses, ranging from 0.01 g to 100 g per kg of body weight, once or more daily, to once every 20 years.

The following examples illustrate the present invention and are not intended to limit the same.

EXAMPLES

EXAMPLE 1: Synthesis of Oligonucleotides

Unmodified oligodeoxynucleotides are synthesized on an automated DNA synthesizer (Applied Biosystems model 380B) using standard phosphoramidite chemistry with oxidation by iodine. β -cyanoethyl-diisopropyl-phosphoramidites are purchased from Applied Biosystems (Foster City, CA). For phosphorothioate oligonucleotides, the standard oxidation bottle was replaced by a 0.2 M solution of 3H -1,2-benzodithiole-3-one 1,1-dioxide in acetonitrile for the stepwise thiation of the phosphite linkages. The thiation cycle wait step was increased to 68

seconds and was followed by the capping step. Cytosines may be 5-methyl cytosines. (5-methyl deoxycytidine phosphoramidites available from Glen Research, Sterling, VA or Amersham Pharmacia Biotech, Piscataway, NJ)

5 2'-methoxy oligonucleotides are synthesized using 2'-methoxy β -cyanoethyl-diisopropyl-phosphoramidites (Chemgenes, Needham, MA) and the standard cycle for unmodified oligonucleotides, except the wait step after pulse delivery of tetrazole and base is increased to 360
10 seconds. Other 2'-alkoxy oligonucleotides are synthesized by a modification of this method, using appropriate 2'-modified amidites such as those available from Glen Research, Inc., Sterling, VA.

2'-fluoro oligonucleotides are synthesized as
15 described in Kawasaki et al. (*J. Med. Chem.* **1993**, 36, 831-841). Briefly, the protected nucleoside N⁶-benzoyl-2'-deoxy-2'-fluoroadenosine is synthesized utilizing commercially available 9- β -D-arabinofuranosyladenine as starting material and by modifying literature procedures
20 whereby the 2'-a-fluoro atom is introduced by a S_N2-displacement of a 2'- β -O-triflyl group. Thus N⁶-benzoyl-9- β -D-arabinofuranosyladenine is selectively protected in moderate yield as the 3',5'-ditetrahydropyranyl (THP) intermediate. Deprotection of the THP and N⁶-benzoyl groups
25 is accomplished using standard methodologies and standard methods are used to obtain the 5'-dimethoxytrityl- (DMT) and 5'-DMT-3'-phosphoramidite intermediates.

The synthesis of 2'-deoxy-2'-fluoroguanosine is accomplished using tetraisopropylidisiloxanyl (TPDS)
30 protected 9- β -D-arabinofuranosylguanine as starting material, and conversion to the intermediate diisobutyryl-arabinofuranosylguanosine. Deprotection of the TPDS group is followed by protection of the hydroxyl group with THP to give diisobutyryl di-THP protected arabinofuranosylguanine.
35 Selective O-deacylation and triflation is followed by treatment of the crude product with fluoride, then

deprotection of the THP groups. Standard methodologies are used to obtain the 5'-DMT- and 5'-DMT-3'-phosphoramidites.

Synthesis of 2'-deoxy-2'-fluorouridine is accomplished by the modification of a known procedure in which 2, 2'-anhydro-1- β -D-arabinofuranosyluracil is treated with 70% hydrogen fluoride-pyridine. Standard procedures are used to obtain the 5'-DMT and 5'-DMT-3'phosphoramidites.

2'-deoxy-2'-fluorocytidine is synthesized via amination of 2'-deoxy-2'-fluorouridine, followed by selective protection to give N⁴-benzoyl-2'-deoxy-2'-fluorocytidine. Standard procedures are used to obtain the 5'-DMT and 5'-DMT-3'phosphoramidites.

2'-(2-methoxyethyl)-modified amidites were synthesized according to Martin, P. (*Helv. Chim. Acta* 1995, 78, 486-506). For ease of synthesis, the last nucleotide may be a deoxynucleotide. 2'-O-CH₂CH₂OCH₃ cytosines may be 5-methyl cytosines.

Synthesis of 5-Methyl cytosine monomers:

2,2'-Anhydro[1-(β -D-arabinofuranosyl)-5-methyluridine]:

5-Methyluridine (ribosylthymine, commercially available through Yamasa, Choshi, Japan) (72.0 g, 0.279 M), diphenylcarbonate (90.0 g, 0.420 M) and sodium bicarbonate (2.0 g, 0.024 M) were added to DMF (300 mL). The mixture was heated to reflux, with stirring, allowing the evolved carbon dioxide gas to be released in a controlled manner. After 1 hour, the slightly darkened solution was concentrated under reduced pressure. The resulting syrup was poured into diethylether (2.5 L), with stirring. The product formed a gum. The ether was decanted and the residue was dissolved in a minimum amount of methanol (ca. 400 mL). The solution was poured into fresh ether (2.5 L) to yield a stiff gum. The ether was decanted and the gum was dried in a vacuum oven (60°C at 1 mm Hg for 24 h) to give a solid which was crushed to a light tan powder (57 g, 85% crude yield). The material was used as is for further reactions.

2'-O-Methoxyethyl-5-methyluridine:

2,2'-Anhydro-5-methyluridine (195 g, 0.81 M), tris(2-methoxyethyl)borate (231 g, 0.98 M) and 2-methoxyethanol (1.2 L) were added to a 2 L stainless steel pressure vessel and placed in a pre-heated oil bath at 160°C. After heating for 48 hours at 155-160°C, the vessel was opened and the solution evaporated to dryness and triturated with MeOH (200 mL). The residue was suspended in hot acetone (1 L). The insoluble salts were filtered, washed with acetone (150 mL) and the filtrate evaporated. The residue (280 g) was dissolved in CH₃CN (600 mL) and evaporated. A silica gel column (3 kg) was packed in CH₂Cl₂/acetone/MeOH (20:5:3) containing 0.5% Et₃NH. The residue was dissolved in CH₂Cl₂ (250 mL) and adsorbed onto silica (150 g) prior to loading onto the column. The product was eluted with the packing solvent to give 160 g (63%) of product.

2'-O-Methoxyethyl-5'-O-dimethoxytrityl-5-methyluridine:

2'-O-Methoxyethyl-5-methyluridine (160 g, 0.506 M) was co-evaporated with pyridine (250 mL) and the dried residue dissolved in pyridine (1.3 L). A first aliquot of dimethoxytrityl chloride (94.3 g, 0.278 M) was added and the mixture stirred at room temperature for one hour. A second aliquot of dimethoxytrityl chloride (94.3 g, 0.278 M) was added and the reaction stirred for an additional one hour. Methanol (170 mL) was then added to stop the reaction. HPLC showed the presence of approximately 70% product. The solvent was evaporated and triturated with CH₃CN (200 mL). The residue was dissolved in CHCl₃ (1.5 L) and extracted with 2x500 mL of saturated NaHCO₃ and 2x500 mL of saturated NaCl. The organic phase was dried over Na₂SO₄, filtered and evaporated. 275 g of residue was obtained. The residue was purified on a 3.5 kg silica gel column, packed and eluted with EtOAc/Hexane/Acetone (5:5:1) containing 0.5% Et₃NH. The pure fractions were evaporated to give 164 g of product. Approximately 20 g additional was obtained from the impure fractions to give a total yield of 183 g (57%).

3'-O-Acetyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methyluridine:

2'-O-Methoxyethyl-5'-O-dimethoxytrityl-5-methyluridine (106 g, 0.167 M), DMF/pyridine (750 mL of a 3:1 mixture prepared from 562 mL of DMF and 188 mL of pyridine) and acetic anhydride (24.38 mL, 0.258 M) were combined and stirred at room temperature for 24 hours. The reaction was monitored by tlc by first quenching the tlc sample with the addition of MeOH. Upon completion of the reaction, as judged by tlc, MeOH (50 mL) was added and the mixture evaporated at 35°C. The residue was dissolved in CHCl₃ (800 mL) and extracted with 2x200 mL of saturated sodium bicarbonate and 2x200 mL of saturated NaCl. The water layers were back extracted with 200 mL of CHCl₃. The combined organics were dried with sodium sulfate and evaporated to give 122 g of residue (approx. 90% product). The residue was purified on a 3.5 kg silica gel column and eluted using EtOAc/Hexane(4:1). Pure product fractions were evaporated to yield 96 g (84%).

3'-O-Acetyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methyl-4-triazoleuridine:

A first solution was prepared by dissolving 3'-O-acetyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methyluridine (96 g, 0.144 M) in CH₃CN (700 mL) and set aside. Triethylamine (189 mL, 1.44 M) was added to a solution of triazole (90 g, 1.3 M) in CH₃CN (1 L), cooled to -5°C and stirred for 0.5 h using an overhead stirrer. POCl₃ was added dropwise, over a 30 minute period, to the stirred solution maintained at 0-10°C, and the resulting mixture stirred for an additional 2 hours. The first solution was added dropwise, over a 45 minute period, to the later solution. The resulting reaction mixture was stored overnight in a cold room. Salts were filtered from the reaction mixture and the solution was evaporated. The residue was dissolved in EtOAc (1 L) and the insoluble solids were removed by filtration. The filtrate was washed with 1x300 mL of NaHCO₃ and 2x300 mL of saturated NaCl,

dried over sodium sulfate and evaporated. The residue was triturated with EtOAc to give the title compound.

2'-O-Methoxyethyl-5'-O-dimethoxytrityl-5-methylcytidine:

A solution of 3'-O-acetyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methyl-4-triazoleuridine (103 g, 0.141 M) in dioxane (500 mL) and NH_4OH (30 mL) was stirred at room temperature for 2 hours. The dioxane solution was evaporated and the residue azeotroped with MeOH (2x200 mL). The residue was dissolved in MeOH (300 mL) and transferred to a 2 liter stainless steel pressure vessel. MeOH (400 mL) saturated with NH_3 gas was added and the vessel heated to 100°C for 2 hours (tlc showed complete conversion). The vessel contents were evaporated to dryness and the residue was dissolved in EtOAc (500 mL) and washed once with saturated NaCl (200 mL). The organics were dried over sodium sulfate and the solvent was evaporated to give 85 g (95%) of the title compound.

N^4 -Benzoyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methylcytidine:

2'-O-Methoxyethyl-5'-O-dimethoxytrityl-5-methylcytidine (85 g, 0.134 M) was dissolved in DMF (800 mL) and benzoic anhydride (37.2 g, 0.165 M) was added with stirring. After stirring for 3 hours, tlc showed the reaction to be approximately 95% complete. The solvent was evaporated and the residue azeotroped with MeOH (200 mL). The residue was dissolved in CHCl_3 (700 mL) and extracted with saturated NaHCO_3 (2x300 mL) and saturated NaCl (2x300 mL), dried over MgSO_4 and evaporated to give a residue (96 g). The residue was chromatographed on a 1.5 kg silica column using EtOAc/Hexane (1:1) containing 0.5% Et_3NH as the eluting solvent. The pure product fractions were evaporated to give 90 g (90%) of the title compound.

N^4 -Benzoyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methylcytidine-3'-amidite:

N^4 -Benzoyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methylcytidine (74 g, 0.10 M) was dissolved in CH_2Cl_2 (1 L). Tetrazole diisopropylamine (7.1 g) and 2-cyanoethoxy-

tetra(isopropyl)phosphite (40.5 mL, 0.123 M) were added with stirring, under a nitrogen atmosphere. The resulting mixture was stirred for 20 hours at room temperature (tlc showed the reaction to be 95% complete). The reaction
5 mixture was extracted with saturated NaHCO₃ (1x300 mL) and saturated NaCl (3x300 mL). The aqueous washes were back-extracted with CH₂Cl₂ (300 mL), and the extracts were combined, dried over MgSO₄ and concentrated. The residue obtained was chromatographed on a 1.5 kg silica column
10 using EtOAc\Hexane (3:1) as the eluting solvent. The pure fractions were combined to give 90.6 g (87%) of the title compound.

5-methyl-2'-deoxycytidine (5-me-C) containing oligonucleotides were synthesized according to published
15 methods (Sanghvi et al., *Nucl. Acids Res.* **1993**, *21*, 3197-3203) using commercially available phosphoramidites (Glen Research, Sterling VA or ChemGenes, Needham MA).

2=-O-(dimethylaminooxyethyl) nucleoside amidites

2'-(Dimethylaminooxyethoxy) nucleoside amidites [also
20 known in the art as 2'-O-(dimethylaminooxyethyl) nucleoside amidites] are prepared as described in the following paragraphs. Adenosine, cytidine and guanosine nucleoside amidites are prepared similarly to the thymidine (5-methyluridine) except the exocyclic amines are protected
25 with a benzoyl moiety in the case of adenosine and cytidine and with isobutyryl in the case of guanosine.

5'-O-tert-Butyldiphenylsilyl-O²-2'-anhydro-5-methyluridine

O²-2'-anhydro-5-methyluridine (Pro. Bio. Sint.,
30 Varese, Italy, 100.0g, 0.416 mmol), dimethylaminopyridine (0.66g, 0.013eq, 0.0054mmol) were dissolved in dry pyridine (500 ml) at ambient temperature under an argon atmosphere and with mechanical stirring. tert-Butyldiphenylchlorosilane (125.8g, 119.0mL, 1.1eq,
35 0.458mmol) was added in one portion. The reaction was stirred for 16 h at ambient temperature. TLC (R_f 0.22, ethyl acetate) indicated a complete reaction. The solution

was concentrated under reduced pressure to a thick oil. This was partitioned between dichloromethane (1 L) and saturated sodium bicarbonate (2x1 L) and brine (1 L). The organic layer was dried over sodium sulfate and
5 concentrated under reduced pressure to a thick oil. The oil was dissolved in a 1:1 mixture of ethyl acetate and ethyl ether (600mL) and the solution was cooled to -10°C. The resulting crystalline product was collected by filtration, washed with ethyl ether (3x200 mL) and dried
10 (40°C, 1mm Hg, 24 h) to 149g (74.8%) of white solid. TLC and NMR were consistent with pure product.
5'-O-tert-Butyldiphenylsilyl-2'-O-(2-hydroxyethyl)-5-methyluridine

In a 2 L stainless steel, unstirred pressure reactor
15 was added borane in tetrahydrofuran (1.0 M, 2.0 eq, 622 mL). In the fume hood and with manual stirring, ethylene glycol (350 mL, excess) was added cautiously at first until the evolution of hydrogen gas subsided. 5'-O-tert-Butyldiphenylsilyl-O²-2'-anhydro-5-methyluridine (149 g,
20 0.311 mol) and sodium bicarbonate (0.074 g, 0.003 eq) were added with manual stirring. The reactor was sealed and heated in an oil bath until an internal temperature of 160 °C was reached and then maintained for 16 h (pressure < 100 psig). The reaction vessel was cooled to ambient and
25 opened. TLC (Rf 0.67 for desired product and Rf 0.82 for ara-T side product, ethyl acetate) indicated about 70% conversion to the product. In order to avoid additional side product formation, the reaction was stopped, concentrated under reduced pressure (10 to 1mm Hg) in a
30 warm water bath (40-100°C) with the more extreme conditions used to remove the ethylene glycol. [Alternatively, once the low boiling solvent is gone, the remaining solution can be partitioned between ethyl acetate and water. The product will be in the organic phase.] The residue was
35 purified by column chromatography (2kg silica gel, ethyl acetate-hexanes gradient 1:1 to 4:1). The appropriate fractions were combined, stripped and dried to product as a

white crisp foam (84g, 50%), contaminated starting material (17.4g) and pure reusable starting material 20g. The yield based on starting material less pure recovered starting material was 58%. TLC and NMR were consistent with 99%
5 pure product.

2'-O-([2-phthalimidoxy)ethyl]-5'-t-butyldiphenylsilyl-5-methyluridine

5'-O-tert-Butyldiphenylsilyl-2'-O-(2-hydroxyethyl)-5-methyluridine (20g, 36.98mmol) was mixed with
10 triphenylphosphine (11.63g, 44.36mmol) and N-hydroxyphthalimide (7.24g, 44.36mmol). It was then dried over P_2O_5 under high vacuum for two days at 40°C. The reaction mixture was flushed with argon and dry THF (369 mL, Aldrich, sure seal bottle) was added to get a clear
15 solution. Diethyl-azodicarboxylate (6.98mL, 44.36mmol) was added dropwise to the reaction mixture. The rate of addition is maintained such that resulting deep red coloration is just discharged before adding the next drop. After the addition was complete, the reaction was stirred
20 for 4 hrs. By that time TLC showed the completion of the reaction (ethylacetate:hexane, 60:40). The solvent was evaporated in vacuum. Residue obtained was placed on a flash column and eluted with ethyl acetate:hexane (60:40), to get 2'-O-([2-phthalimidoxy)ethyl]-5'-t-
25 butyldiphenylsilyl-5-methyluridine as white foam (21.81g, 86%).

5'-O-tert-butyldiphenylsilyl-2'-O-[(2-formadoximinooxy)ethyl]-5-methyluridine

2'-O-([2-phthalimidoxy)ethyl]-5'-t-
30 butyldiphenylsilyl-5-methyluridine (3.1g, 4.5mmol) was dissolved in dry CH_2Cl_2 (4.5mL) and methylhydrazine (300mL, 4.64mmol) was added dropwise at -10°C to 0°C. After 1 hr the mixture was filtered, the filtrate was washed with ice cold CH_2Cl_2 and the combined organic phase was washed with
35 water, brine and dried over anhydrous Na_2SO_4 . The solution was concentrated to get 2'-O-(aminooxyethyl) thymidine,

which was then dissolved in MeOH (67.5mL). To this formaldehyde (20% aqueous solution, w/w, 1.1eq.) was added and the mixture for 1 hr. Solvent was removed under vacuum; residue chromatographed to get 5'-O-tert-butyldiphenylsilyl-2'-O-[(2-formadoximinooxy) ethyl]-5-methyluridine as white foam (1.95, 78%).

5'-O-tert-Butyldiphenylsilyl-2'-O-[N,N-dimethylaminooxyethyl]-5-methyluridine

5'-O-tert-butylidiphenylsilyl-2'-O-[(2-formadoximinooxy)ethyl]-5-methyluridine (1.77g, 3.12mmol) was dissolved in a solution of 1M pyridinium p-toluenesulfonate (PPTS) in dry MeOH (30.6mL). Sodium cyanoborohydride (0.39g, 6.13mmol) was added to this solution at 10°C under inert atmosphere. The reaction mixture was stirred for 10 minutes at 10°C. After that the reaction vessel was removed from the ice bath and stirred at room temperature for 2 hr, the reaction monitored by TLC (5% MeOH in CH₂Cl₂). Aqueous NaHCO₃ solution (5%, 10mL) was added and extracted with ethyl acetate (2x20mL). Ethyl acetate phase was dried over anhydrous Na₂SO₄, evaporated to dryness. Residue was dissolved in a solution of 1M PPTS in MeOH (30.6mL). Formaldehyde (20% w/w, 30mL, 3.37mmol) was added and the reaction mixture was stirred at room temperature for 10 minutes. Reaction mixture cooled to 10°C in an ice bath, sodium cyanoborohydride (0.39g, 6.13mmol) was added and reaction mixture stirred at 10°C for 10 minutes. After 10 minutes, the reaction mixture was removed from the ice bath and stirred at room temperature for 2 hrs. To the reaction mixture 5% NaHCO₃ (25mL) solution was added and extracted with ethyl acetate (2x25mL). Ethyl acetate layer was dried over anhydrous Na₂SO₄ and evaporated to dryness. The residue obtained was purified by flash column chromatography and eluted with 5% MeOH in CH₂Cl₂ to get 5'-O-tert-butylidiphenylsilyl-2'-O-[N,N-dimethylaminooxyethyl]-5-methyluridine as a white foam (14.6g, 80%).

2'-O-(dimethylaminoxyethyl)-5-methyluridine

Triethylamine trihydrofluoride (3.91mL, 24.0mmol) was dissolved in dry THF and triethylamine (1.67mL, 12mmol, dry, kept over KOH). This mixture of triethylamine-2HF was then added to 5'-O-tert-butyldiphenylsilyl-2'-O-[N,N-dimethylaminoxyethyl]-5-methyluridine (1.40g, 2.4mmol) and stirred at room temperature for 24 hrs. Reaction was monitored by TLC (5% MeOH in CH₂Cl₂). Solvent was removed under vacuum and the residue placed on a flash column and eluted with 10% MeOH in CH₂Cl₂ to get 2'-O-(dimethylaminoxyethyl)-5-methyluridine (766mg, 92.5%).

5'-O-DMT-2'-O-(dimethylaminoxyethyl)-5-methyluridine

2'-O-(dimethylaminoxyethyl)-5-methyluridine (750mg, 2.17mmol) was dried over P₂O₅ under high vacuum overnight at 40°C. It was then co-evaporated with anhydrous pyridine (20mL). The residue obtained was dissolved in pyridine (11mL) under argon atmosphere. 4-dimethylaminopyridine (26.5mg, 2.60mmol), 4,4'-dimethoxytrityl chloride (880mg, 2.60mmol) was added to the mixture and the reaction mixture was stirred at room temperature until all of the starting material disappeared. Pyridine was removed under vacuum and the residue chromatographed and eluted with 10% MeOH in CH₂Cl₂ (containing a few drops of pyridine) to get 5'-O-DMT-2'-O-(dimethylamino-oxyethyl)-5-methyluridine (1.13g, 80%).

5'-O-DMT-2'-O-(2-N,N-dimethylaminoxyethyl)-5-methyluridine-3'-[(2-cyanoethyl)-N,N-diisopropylphosphoramidite]

5'-O-DMT-2'-O-(dimethylaminoxyethyl)-5-methyluridine (1.08g, 1.67mmol) was co-evaporated with toluene (20mL). To the residue N,N-diisopropylamine tetrazonide (0.29g, 1.67mmol) was added and dried over P₂O₅ under high vacuum overnight at 40°C. Then the reaction mixture was dissolved in anhydrous acetonitrile (8.4mL) and 2-cyanoethyl-N,N,N¹,N¹-tetraisopropylphosphoramidite (2.12mL, 6.08mmol) was added. The reaction mixture was stirred at ambient temperature for 4 hrs under inert atmosphere. The progress of the reaction was monitored by TLC (hexane:ethyl acetate

1:1). The solvent was evaporated, then the residue was dissolved in ethyl acetate (70mL) and washed with 5% aqueous NaHCO₃ (40mL). Ethyl acetate layer was dried over anhydrous Na₂SO₄ and concentrated. Residue obtained was
5 chromatographed (ethyl acetate as eluent) to get 5'-O-DMT-2'-O-(2-N,N-dimethylaminooxyethyl)-5-methyluridine-3'-[(2-cyanoethyl)-N,N-diisopropylphosphoramidite] as a foam (1.04g, 74.9%).

Oligonucleotides having methylene(methylimino) (MMI)
10 backbones are synthesized according to U.S. Patent 5,378,825, which is coassigned to the assignee of the present invention and is incorporated herein in its entirety. For ease of synthesis, various nucleoside dimers containing MMI linkages are synthesized and incorporated
15 into oligonucleotides. Other nitrogen-containing backbones are synthesized according to WO 92/20823 which is also coassigned to the assignee of the present invention and incorporated herein in its entirety.

Oligonucleotides having amide backbones are
20 synthesized according to De Mesmaeker *et al.* (*Acc. Chem. Res.* **1995**, *28*, 366-374). The amide moiety is readily accessible by simple and well-known synthetic methods and is compatible with the conditions required for solid phase synthesis of oligonucleotides.

25 Oligonucleotides with morpholino backbones are synthesized according to U.S. Patent 5,034,506 (Summerton and Weller).

Peptide-nucleic acid (PNA) oligomers are synthesized according to P.E. Nielsen *et al.* (*Science* **1991**, *254*, 1497-
30 1500).

After cleavage from the controlled pore glass column (Applied Biosystems) and deblocking in concentrated ammonium hydroxide at 55°C for 18 hours, the oligonucleotides are purified by precipitation twice out of
35 0.5 M NaCl with 2.5 volumes ethanol. Synthesized oligonucleotides were analyzed by polyacrylamide gel electrophoresis on denaturing gels or capillary gel

electrophoresis and judged to be at least 85% full length material. The relative amounts of phosphorothioate and phosphodiester linkages obtained in synthesis were periodically checked by ³¹P nuclear magnetic resonance spectroscopy, and for some studies oligonucleotides were purified by HPLC, as described by Chiang et al. (*J. Biol. Chem.* 1991, 266, 18162). Results obtained with HPLC-purified material were similar to those obtained with non-HPLC purified material.

Alternatively, oligonucleotides were synthesized in 96 well plate format via solid phase P(III) phosphoramidite chemistry on an automated synthesizer capable of assembling 96 sequences simultaneously in a standard 96 well format. Phosphodiester internucleotide linkages were afforded by oxidation with aqueous iodine. Phosphorothioate internucleotide linkages were generated by sulfurization utilizing 3,4-dihydro-2H-benzothiole-3-one 1,1-dioxide (Beaucage Reagent) in anhydrous acetonitrile. Standard base-protected beta-cyanoethyl-di-isopropyl phosphoramidites were purchased from commercial vendors (e.g. PE-Applied Biosystems, Foster City, CA, or Pharmacia, Piscataway, NJ).

Non-standard nucleosides are synthesized as per published methods. They are utilized as base protected beta-cyanoethyl-diisopropyl phosphoramidites.

Oligonucleotides were cleaved from support and deprotected with concentrated NH₄OH at elevated temperature (55-60°C) for 12-16 hours and the released product then dried in vacuo. The dried product was then re-suspended in sterile water to afford a master plate from which all analytical and test plate samples are then diluted utilizing robotic pipettors.

EXAMPLE 2: Human STAT3 Oligodeoxynucleotide Sequences

Antisense oligonucleotides were designed to target human STAT3. Target sequence data are from the APRF cDNA sequence published by Akira, S. et al. (*Cell*, 1994, 77, 63-

71); Genbank accession number L29277, provided herein as SEQ ID NO: 1. A set of oligodeoxynucleotides were synthesized with phosphorothioate linkages. 2'-deoxy cytosines were 5-methyl cytosines. These oligonucleotide sequences are shown in Table 1. An additional set of oligonucleotides was synthesized as chimeric oligonucleotides ("gapmers") 20 nucleotides in length, composed of a central "gap" region consisting of ten 2'-deoxynucleotides, which is flanked on both sides (5' and 3' directions) by five-nucleotide "wings." The wings are composed of 2'-methoxyethyl (2'-MOE)nucleotides. The internucleoside (backbone) linkages are phosphorothioate (P=S) throughout the oligonucleotide. All 2'-MOE cytosines and 2'-deoxy cytosines were 5-methyl-cytosines. These oligonucleotide sequences are shown in Table 2.

An appropriate cell line, typically expressing high levels of STAT3, is chosen for *in vitro* studies. Cell culture conditions are those standard for that particular cell line. Oligonucleotide treatment is for four hours and mRNA usually isolated 24 to 48 hours following initial treatment. mRNA is isolated using the RNeasy7 kit (Qiagen, Santa Clarita, CA).

TABLE 1:
Nucleotide Sequences of Human STAT3 Phosphorothioate Oligodeoxynucleotides

ISIS NO.	NUCLEOTIDE SEQUENCE ¹ (5' -> 3')	SEQ ID NO:	TARGET GENE NUCLEOTIDE CO-ORDINATES ²	GENE TARGET REGION
106691	GTCTGCGCCGCGCCCCGAA	2	0010-0029	5'-UTR
106692	GGCCGAAGGGCCTCTCCGAG	3	0130-0149	5'-UTR
106693	TCCTGTTTCTCCGGCAGAGG	4	0202-0221	AUG
106694	CATCCTGTTTCTCCGGCAGA	5	0204-0223	AUG
106695	GCCATCCTGTTTCTCCGGCA	6	0206-0225	AUG

106696	GGGCCATCCTGTTTCTCCGG	7	0208-0227	AUG
106697	TTGGGCCATCCTGTTTCTCC	8	0210-0229	AUG
106698	CATTGGGCCATCCTGTTTCT	9	0212-0231	AUG
106699	TCCATTGGGCCATCCTGTTT	10	0214-0233	AUG
106700	ATTCCATTGGGCCATCCTGT	11	0216-0235	AUG
106701	TGATTCCATTGGGCCATCCT	12	0218-0237	AUG
106702	GCTGATTCCATTGGGCCATC	13	0220-0239	AUG
106703	TAGCTGATTCCATTGGGCCA	14	0222-0241	AUG
106704	TGTAGCTGATTCCATTGGGC	15	0224-0243	coding
106705	CTGTAGAGCTGATGGAGCTG	16	0269-0288	coding
106706	CCCAATCTTGACTCTCAATC	17	0331-0350	coding
106707	CCCAGGAGATTATGAAACAC	18	0386-0405	coding
106708	ACATTCGACTCTTGACAGAA	19	0431-0450	coding
106709	TCTGAAGAACTGCTTGATT	20	0475-0494	coding
106710	GGCCACAATCCGGGCAATCT	21	0519-0538	coding
106711	TGGCTGCAGTCTGTAGAAGG	22	0562-0581	coding
106712	CTGCTCCAGCATCTGCTGCT	23	0639-0658	coding
106713	TTTCTGTTCTAGATCCTGCA	24	0684-0703	coding
106714	TAGTTGAAATCAAAGTCATC	25	0728-0747	coding
106715	TTCCATTCAGATCTTGCAATG	26	0772-0791	coding
106716	TCTGTTCCAGCTGCTGCATC	27	0817-0836	coding
106717	TCACTCACGATGCTTCTCCG	28	0860-0879	coding
106718	GAGTTTTCTGCACGTACTCC	29	0904-0923	coding
106719	ATCTGTTGCCGCTCTTCCA	30	0947-0968	coding
106720	CTAGCCGATCTAGGCAGATG	31	0991-1010	coding
106721	CGGGTCTGAAGTTGAGATTC	32	1034-1053	coding

106722	CGGCCGGTGCTGTACAATGG	33	1110-1129	coding
106723	TTTCATTAAGTTTCTGAACA	34	1155-1174	coding
106724	AGGATGCATGGGCATGCAGG	35	1200-1219	coding
106725	GACCAGCAACCTGACTTTAG	36	1260-1279	coding
106726	ATGCACACTTTAATTTTAAG	37	1304-1323	coding
106727	TTCCGGGATCCTCTGAGAGC	38	1349-1368	coding
106728	TTCCATGTTTCATCACTTTTG	39	1392-1411	coding
106729	GTCAAGTGTTTGAATTCTGC	40	1436-1455	coding
106730	CAATCAGGGAAGCATCACAA	41	1495-1514	coding
106731	TACACCTCGGTCTCAAAGGT	42	1538-1557	coding
106732	TGACAAGGAGTGGGTCTCTA	43	1581-1600	coding
106733	CGCCCAGGCATTTGGCATCT	44	1626-1645	coding
106734	CATTCTTGGGATTGTTGGTC	45	1669-1688	coding
106735	CACTTGGTCCCAGGTTCCAA	46	1713-1732	coding
106736	CCCGCTTGGTGGTGGACGAG	47	1756-1775	coding
106737	AGTTCACACCAGGCCCTAGG	48	1816-1835	coding
106738	GTTTTCTTTGCAGAAAGTTAG	49	1860-1879	coding
106739	ATATTGTCTAGCCAGACCCA	50	1904-1923	coding
106740	AACCCATGATGTACCCTTCA	51	1963-1982	coding
106741	GCTTAGTGCTCAAGATGGCC	52	2005-2024	coding
106742	GCTGCTTTCACTGAAGCGCA	53	2043-2062	coding
106743	GTGAAAGTGACGCCTCCTTC	54	2066-2085	coding
106744	CTGATGTCCTTCTCCACCCA	55	2087-2106	coding
106745	ACTGGATCTGGGTCTTACCG	56	2107-2126	coding
106746	AAATGACATGTTGTTTACGCT	57	2151-2170	coding
106747	GCCCATGATGATTTTACAGCAA	58	2169-2188	coding

106748	TATTGGTAGCATCCATGATC	59	2194-2213	coding
106749	ATAGACAAGTGGAGACAACA	60	2217-2236	coding
106750	TTGGGAATGTCAGGATAGAG	61	2237-2256	coding
106751	CTCCTGGCTCTCTGGCCGAC	62	2280-2299	coding
106752	ACCTGGGTCAGCTTCAGGAT	63	2301-2320	coding
106753	CACAGATAAACTTGGTCTTC	64	2338-2357	coding
106754	ATCGGCAGGTCAATGGTATT	65	2378-2397	coding
106755	CCAAACTGCATCAATGAATC	66	2414-2433	coding
106756	GGTTCAGCACCTTCACCATT	67	2438-2457	coding
106757	GAGGGACTCAAAGTGCCTC	68	2466-2485	coding
106758	CAACTCCATGTCAAAGGTGA	69	2484-2503	coding
106759	TTCTCAGCTCCTCACATGGG	70	2525-2544	STOP
106760	CGTTCTCAGCTCCTCACATG	71	2527-2546	STOP
106761	TCCGTTCTCAGCTCCTCACA	72	2529-2548	STOP
106762	CTTCCGTTCTCAGCTCCTCA	73	2531-2550	STOP
106763	AGCTTCCGTTCTCAGCTCCT	74	2533-2552	STOP
106764	AGAATGCAGGTAGGCGCCTC	75	2569-2588	3'-UTR
106765	ACCACAAAGTTAGTAGTTTC	76	2623-2642	3'-UTR
106766	TGCTCAAAGATAGCAGAAGT	77	2665-2684	3'-UTR
106767	ATTCACTCATTTCTCTATTT	78	2701-2720	3'-UTR
106768	CATTTAGATAAAAGCAGATC	79	2727-2746	3'-UTR
106769	ACATCCTTATTTGCATTTAG	80	2740-2759	3'-UTR
106770	GATCATGGGTCTCAGAGAAC	81	2760-2779	3'-UTR

¹ "C" residues are 5-methyl-cytosines; all linkages are phosphorothioate linkages.

² Coordinates from Genbank Accession No. L29277, locus name "HUMAPRF", SEQ ID NO. 1.

TABLE 2:
Nucleotide Sequences of Human STAT3 Chimeric (deoxy gapped)
Phosphorothioate Oligonucleotides

ISIS NO.	NUCLEOTIDE SEQUENCE ¹ (5' -> 3')	SEQ ID NO:	TARGET GENE NUCLEOTIDE CO-ORDINATES ²	GENE TARGET REGION
106771	GTCTGCGCCGCGCCCGAA	2	0010-0029	5'-UTR
106772	GGCCGAAGGGCCTCTCCGAG	3	0130-0149	5'-UTR
106773	TCCTGTTTCTCCGGCAGAGG	4	0202-0221	AUG
106774	CATCCTGTTTCTCCGGCAGA	5	0204-0223	AUG
106775	GCCATCCTGTTTCTCCGGCA	6	0206-0225	AUG
106776	GGGCCATCCTGTTTCTCCGG	7	0208-0227	AUG
106777	TTGGGCCATCCTGTTTCTCC	8	0210-0229	AUG
106778	CATTGGGCCATCCTGTTTCT	9	0212-0231	AUG
106779	TCCATTGGGCCATCCTGTTT	10	0214-0233	AUG
106780	ATTCCATTGGGCCATCCTGT	11	0216-0235	AUG
106781	TGATTCCATTGGGCCATCCT	12	0218-0237	AUG
106782	GCTGATTCCATTGGGCCATC	13	0220-0239	AUG
106783	TAGCTGATTCCATTGGGCCA	14	0222-0241	AUG
106784	TGTAGCTGATTCCATTGGGC	15	0224-0243	coding
106785	CTGTAGAGCTGATGGAGCTG	16	0269-0288	coding
106786	CCCAATCTTGACTCTCAATC	17	0331-0350	coding
106787	CCCAGGAGATTATGAAACAC	18	0386-0405	coding
106788	ACATTCGACTCTTGACAGGAA	19	0431-0450	coding
106789	TCTGAAGAACTGCTTGATT	20	0475-0494	coding
106790	GGCCACAATCCGGGCAATCT	21	0519-0538	coding
106791	TGGCTGCAGTCTGTAGAAGG	22	0562-0581	coding
106792	CTGCTCCAGCATCTGCTGCT	23	0639-0658	coding

106793	TTTCTGTTCTAGATCCTGCA	24	0684-0703	coding
106794	TAGTTGAAATCAAAGTCATC	25	0728-0747	coding
106795	TTCCATTGAGATCTTGCATG	26	0772-0791	coding
106796	TCTGTTCCAGCTGCTGCATC	27	0817-0836	coding
106797	TCACTCACGATGCTTCTCCG	28	0860-0879	coding
106798	GAGTTTTCTGCACGTACTCC	29	0904-0923	coding
106799	ATCTGTTGCCGCCTCTTCCA	30	0947-0968	coding
106800	CTAGCCGATCTAGGCAGATG	31	0991-1010	coding
106801	CGGGTCTGAAGTTGAGATTC	32	1034-1053	coding
106802	CGGCCGGTGCTGTACAATGG	33	1110-1129	coding
106803	TTTCATTAAGTTTCTGAACA	34	1155-1174	coding
106804	AGGATGCATGGGCATGCAGG	35	1200-1219	coding
106805	GACCAGCAACCTGACTTTAG	36	1260-1279	coding
106806	ATGCACACTTTAATTTTAAG	37	1304-1323	coding
106807	TTCCGGGATCCTCTGAGAGC	38	1349-1368	coding
106808	TTCCATGTTTCATCACTTTTG	39	1392-1411	coding
106809	GTCAAGTGTTTGAATTCTGC	40	1436-1455	coding
106810	CAATCAGGGAAGCATCACAA	41	1495-1514	coding
106811	TACACCTCGGTCTCAAAGGT	42	1538-1557	coding
106812	TGACAAGGAGTGGGTCTCTA	43	1581-1600	coding
106813	CGCCCAGGCATTGGCATCT	44	1626-1645	coding
106814	CATTCTTGGGATTGTTGGTC	45	1669-1688	coding
106815	CACTTGGTCCCAGGTTCCAA	46	1713-1732	coding
106816	CCCGCTTGGTGGTGGACGAG	47	1756-1775	coding
106817	AGTTCACACCAGGCCCTAGG	48	1816-1835	coding
106818	GTTTTCTTTGCAGAAGTTAG	49	1860-1879	coding

106819	ATATTGTCTAGCCAGACCCA	50	1904-1923	coding
106820	AACCCATGATGTACCCTTCA	51	1963-1982	coding
106821	GCTTAGTGCTCAAGATGGCC	52	2005-2024	coding
106822	GCTGCTTTCACTGAAGCGCA	53	2043-2062	coding
106823	GTGAAAGTGACGCCTCCTTC	54	2066-2085	coding
106824	CTGATGTCCTTCTCCACCCA	55	2087-2106	coding
106825	ACTGGATCTGGGTCTTACCG	56	2107-2126	coding
106826	AAATGACATGTTGTTTCAGCT	57	2151-2170	coding
106827	GCCCATGATGATTTTCAGCAA	58	2169-2188	coding
106828	TATTGGTAGCATCCATGATC	59	2194-2213	coding
106829	ATAGACAAGTGGAGACAACA	60	2217-2236	coding
106830	TTGGGAATGTCAGGATAGAG	61	2237-2256	coding
106831	CTCCTGGCTCTCTGGCCGAC	62	2280-2299	coding
106832	ACCTGGGTCAGCTTCAGGAT	63	2301-2320	coding
106833	CACAGATAAACTTGGTCTTC	64	2338-2357	coding
106834	ATCGGCAGGTCAATGGTATT	65	2378-2397	coding
106835	CCAAACTGCATCAATGAATC	66	2414-2433	coding
106836	GGTTCAGCACCTTCACCATT	67	2438-2457	coding
106837	GAGGGACTCAAAC TGCCCTC	68	2466-2485	coding
106838	CAACTCCATGTCAAAGGTGA	69	2484-2503	coding
106839	TTCTCAGCTCCTCACATGGG	70	2525-2544	STOP
106840	CGTTCTCAGCTCCTCACATG	71	2527-2546	STOP
106841	TCCGTTCTCAGCTCCTCACA	72	2529-2548	STOP
106842	CTTCCGTTCTCAGCTCCTCA	73	2531-2550	STOP
106843	AGCTTCCGTTCTCAGCTCCT	74	2533-2552	STOP
106844	AGAATGCAGGTAGGCGCCTC	75	2569-2588	3' -UTR

106845	ACCACAAAGTTAGTAGTTTC	76	2623-2642	3'-UTR
106846	TGCTCAAAGATAGCAGAAGT	77	2665-2684	3'-UTR
106847	ATTCACCTCATTTCTCTATTT	78	2701-2720	3'-UTR
106848	CATTTAGATAAAAGCAGATC	79	2727-2746	3'-UTR
106849	ACATCCTTATTTGCATTTAG	80	2740-2759	3'-UTR
106850	GATCATGGGTCTCAGAGAAC	81	2760-2779	3'-UTR

¹ Emboldened residues are 2'-methoxyethoxy residues, 2'-methoxyethoxy cytosine residues and 2'-OH cytosine residues are 5-methyl-cytosines; all linkages are phosphorothioate linkages.

² Coordinates from Genbank Accession No. L29277, locus name "HUMAPRF", SEQ ID NO. 1.

Oligonucleotide activity is assayed by quantitation of STAT3 mRNA levels by real-time PCR (RT-PCR) using the ABI PRISM™ 7700 Sequence Detection System (PE-Applied Biosystems, Foster City, CA) according to manufacturer's instructions. This is a closed-tube, non-gel-based, fluorescence detection system which allows high-throughput quantitation of polymerase chain reaction (PCR) products in real-time. As opposed to standard PCR, in which amplification products are quantitated after the PCR is completed, products in RT-PCR are quantitated as they accumulate. This is accomplished by including in the PCR reaction an oligonucleotide probe that anneals specifically between the forward and reverse PCR primers, and contains two fluorescent dyes. A reporter dye (e.g., JOE or FAM, PE-Applied Biosystems, Foster City, CA) is attached to the 5' end of the probe and a quencher dye (e.g., TAMRA, PE-Applied Biosystems, Foster City, CA) is attached to the 3' end of the probe. When the probe and dyes are intact, reporter dye emission is quenched by the proximity of the 3' quencher dye. During amplification, annealing of the

probe to the target sequence creates a substrate that can be cleaved by the 5'-exonuclease activity of Taq polymerase. During the extension phase of the PCR amplification cycle, cleavage of the probe by Taq polymerase releases the reporter dye from the remainder of the probe (and hence from the quencher moiety) and a sequence-specific fluorescent signal is generated. With each cycle, additional reporter dye molecules are cleaved from their respective probes, and the fluorescence intensity is monitored at regular (six-second) intervals by laser optics built into the ABI PRISM™ 7700 Sequence Detection System. In each assay, a series of parallel reactions containing serial dilutions of mRNA from untreated control samples generates a standard curve that is used to quantitate the percent inhibition after antisense oligonucleotide treatment of test samples.

RT-PCR reagents are obtained from PE-Applied Biosystems, Foster City, CA. RT-PCR reactions are carried out by adding 25 μ l PCR cocktail (1x TAQMAN7 buffer A, 5.5 mM MgCl₂, 300 μ M each of dATP, dCTP and dGTP, 600 μ M of dUTP, 100 nM each of forward primer, reverse primer, and probe, 20 U RNase inhibitor, 1.25 units AMPLITAQ GOLD7, and 12.5 U MuLV reverse transcriptase) to 96 well plates containing 25 μ l poly(A) mRNA solution. The RT reaction is carried out by incubation for 30 minutes at 48°C. following a 10 minute incubation at 95°C to activate the AMPLITAQ GOLD7, 40 cycles of a two-step PCR protocol are carried out: 95°C for 15 seconds (denaturation) followed by 60°C for 1.5 minutes (annealing/extension).

STAT3 PCR primers and a probe can be designed using commercial software (e.g. Oligo 5.0).

EXAMPLE 3: Mouse STAT3 Oligonucleotide Sequences

Antisense oligonucleotides were designed to target mouse STAT3. Target sequence data are from the STAT3 cDNA sequence submitted by Zhong, Z.; Genbank accession number U06922, provided herein as SEQ ID NO: 82. Oligonucleotides

were synthesized as chimeric oligonucleotides ("gapmers") 20 nucleotides in length, composed of a central "gap" region consisting of ten 2'-deoxynucleotides, which is flanked on both sides (5' and 3' directions) by five-nucleotide "wings." The wings are composed of 2'-methoxyethyl (2'-MOE)nucleotides. The internucleoside (backbone) linkages are phosphorothioate (P=S) throughout the oligonucleotide. All 2'-MOE cytosines were 5-methyl-cytosines. Oligonucleotide sequences are shown in Table 3.

10 The B lymphoma cell line, BCL1 was obtained from ATCC (Rockville, MD). BCL1 cells were cultured in RPMI 1640 medium.

BCL1 cells (5×10^6 cells in PBS) were transfected with oligonucleotides by electroporation, at 200V, 1000°F using a BTX Electro Cell Manipulator 600 (Genetronics, San 15 Diego, CA). For an initial screen, BCL1 were electroporated with 10 M oligonucleotide and RNA collected 24 hours later. Controls without oligonucleotide were subjected to the same electroporation conditions.

20 Total cellular RNA was isolated using the RNEASY7 kit (Qiagen, Santa Clarita, CA). RNase protection experiments were conducted using RIBOQUANT™ kits and template sets according to the manufacturer's instructions (Pharmingen, San Diego, CA). Northern blotting was performed as 25 described in Chiang, M-Y. et al. (*J. Biol. Chem.*, 1991, 266, 18162-18171), using a rat cDNA probe prepared by Xho I/Sal I restriction digest of psvsport-1 plasmid (ATCC, Rockville, MD). mRNA levels were quantitated using a PhosphorImager (Molecular Dynamics, Sunnyvale, CA).

30

TABLE 3:

**Nucleotide Sequences of Mouse STAT3 Chimeric (deoxy gapped)
Phosphorothioate Oligodeoxynucleotides**

ISIS NO.	NUCLEOTIDE SEQUENCE ¹ (5' -> 3')	SEQ ID NO:	TARGET GENE NUCLEOTIDE CO-ORDINATES ²	GENE TARGET REGION
17136	GTTCCACTGAGCCATCCTGC	83	0064-0083	AUG
17137	TTCAGGTAGCGTGTGTCCAG	84	0096-0115	coding
17138	ATGTGACTCTTTGCTGGCTG	85	0205-0224	coding
17139	CCAAGAGATTATGAAACACC	86	0233-0252	coding
17140	GCTCCAACATCTGCTGCTTC	87	0485-0504	coding
17141	GCTCTTCATCAGTCAGTGTC	88	0767-0786	coding
17142	ATCTGACACCCTGAGTAGTT	89	1680-1699	coding
17143	GCCAGACCCAGAAGGAGAAG	90	1742-1761	coding
17144	CGCTCCTTGCTGATGAAACC	91	1827-1846	coding
17145	AACTTGGTCTTCAGGTACGG	92	2178-2197	coding
17146	ATCAATGAATCTAAAGTGCG	93	2253-2272	coding
17147	TCAGCACCTTCACCGTTATT	94	2283-2302	coding
17148	ACTCAAACCTGCCCTCCTGCT	95	2309-2328	coding
17149	GGTTTCAGCTCCTCACATGG	96	2374-2393	STOP
17150	TAAAAAAAAAAATCTGGAAC	97	2485-2504	3'-UTR
17151	AAGATAGCAGAAGTAGGAAA	98	2506-2525	3'-UTR
17152	AAAAAGTGCCCAGATTGCCC	99	2527-2546	3'-UTR
17153	ATCACCCACACTCACTCATT	100	2557-2645	3'-UTR
17154	CCTTTGCCTCCCTTCTGCTC	101	2626-2645	3'-UTR
17155	TGAAAAAGGAGGGCAGGCGG	102	2665-2684	3'-UTR
17156	CACCAGGAGGCACTTGTCTA	103	2705-2724	3'-UTR

17157	AACCTCCTGGGCTTAGTCCT	104	2822-2841	3'-UTR
23176	AAAAAGTGCGCAGATTGCCC	105	1 base mismatch control	
23177	AAAAAGTCCGCTGATTGCCC	106	3 base mismatch control	
23178	AAAAACTCCGCTGAATGCCC	107	5 base mismatch control	

¹ All 2'-MOE cytosine residues are 5-methyl-cytosines; all linkages are phosphorothioate linkages.

5 ²Co-ordinates from Genbank Accession No. U06922, locus name "MMU06922", SEQ ID NO. 82.

Results are shown in Table 4. Oligonucleotides 17138 (SEQ ID NO. 85), 17139 (SEQ ID NO. 86), 17140 (SEQ ID NO. 87), 17143 (SEQ ID NO. 90), 17144 (SEQ ID NO. 91), 17152 (SEQ ID NO. 99), 17153 (SEQ ID NO. 100), 17156 (SEQ ID NO. 103), and 17157 (SEQ ID NO. 104) gave better than 45% inhibition in this assay.

15

TABLE 4

Inhibition of Mouse STAT3 mRNA expression in BCL1 Cells by Chimeric (deoxy gapped) Phosphorothioate Oligonucleotides

ISIS No:	SEQ ID NO:	GENE TARGET REGION	% mRNA EXPRESSION	% mRNA INHIBITION
control	---	---	100%	0%
17136	83	AUG	75%	25%
17137	84	coding	75%	25%
17138	85	coding	37%	63%
17139	86	coding	41%	59%
17140	87	coding	40%	60%
17141	88	coding	62%	38%

17142	89	coding	70%	30%
17143	90	coding	42%	58%
17144	91	coding	55%	45%
17145	92	coding	89%	11%
17146	93	coding	91%	9%
17147	94	coding	70%	30%
17148	95	coding	69%	31%
17149	96	STOP	70%	30%
17150	97	3'-UTR	95%	5%
17151	98	3'-UTR	92%	8%
17152	99	3'-UTR	25%	75%
17153	100	3'-UTR	44%	56%
17154	101	3'-UTR	80%	20%
17155	102	3'-UTR	78%	22%
17156	103	3'-UTR	40%	60%
17157	104	3'-UTR	53%	47%

EXAMPLE 4: Dose response of antisense chimeric (deoxy gapped) phosphorothioate oligonucleotide effects on mouse STAT3 protein levels in BCL1 cells

5 ISIS 17152 (SEQ ID. NO. 99) was chosen for further study. The effect of this oligonucleotide on protein levels was determined by Western blot. ISIS 23177 (SEQ ID NO. 106), a 3 base mismatch, was used as a control. BCL1 cells were grown, treated and processed as described in
10 Example 2.

 Nuclear extracts from primary B cells and B lymphoma cell lines were prepared as described in Karras, J.G., et al. (*J. Exp. Med.*, 1997, 185, 1035-1042).

Western blotting was performed as described in Karras, J.G. et al. (*J. Immunol.*, 1996, 157, 2299). STAT1 and STAT3 antibodies were obtained from UBI (Lake Placid, NY).

5 Results are shown in Table 5. ISIS 17152 (SEQ ID NO. 99) was significantly better at reducing STAT3 protein levels than the mismatch control.

TABLE 5

10 Dose Response of BCL1 cells to STAT3
Chimeric (deoxy gapped) Phosphorothioate Oligonucleotides

ISIS #	SEQ ID NO:	ASO Gene Target	Dose	% protein Expression	% protein Inhibition
control	---	---	---	100%	---
17152	99	3'-UTR	10 nM	41.7%	58.3%
"	"	"	15 nM	42.5%	57.5%
"	"	"	20 nM	26.5%	73.5%
23177	106	control	10 nM	75.1%	24.9%
"	"	"	15 nM	67.6%	32.4%
"	"	"	20 nM	62.6%	37.4%

EXAMPLE 5: Inhibition of BCL1 proliferation by STAT3 antisense chimeric (deoxy gapped) phosphorothioate oligonucleotide

15 The effect of ISIS 17152 (SEQ ID NO. 99) on BCL1 proliferation was determined. BCL1 cells contain constitutively active STAT3 which is thought to be responsible for their proliferation. BCL1 cells were grown, treated and processed as described in Example 2.

20 1 X 10⁵ BCL1 cells were incubated in 96-well plates in 200 L complete RPMI following electroporation. Cultures were pulsed with 1 Ci of [³H]-thymidine for the last 8

hours of culture and cells were harvested and analyzed for thymidine incorporation as described in Francis, D.A. et al. (*Int. Immunol.*, 1995, 7, 151-161) 48 hours after electroporation.

5 Results are shown in Table 6. ISIS 17152 (SEQ ID NO. 99) was able to reduce BCL1 cell proliferation by approximately 50% whereas the mismatch control had no effect.

10

TABLE 6

**Inhibition of BCL1 Cell Proliferation with STAT3
Chimeric (deoxy gapped) Phosphorothioate Oligonucleotides**

ISIS #	SEQ ID NO:	ASO Gene Target	Dose	% Cell Proliferation	% Cell Inhibition
control	---	---	---	100%	---
17152	99	3'-UTR	10 nM	78.5%	21.5%
"	"	"	15 nM	54.4%	45.6%
"	"	"	20 nM	50.2%	49.8%
23177	106	control	10 nM	117.0%	---
"	"	"	15 nM	99.7%	0.3%
"	"	"	20 nM	107.0%	---

15 **EXAMPLE 6: Inhibition of BCL1 IgM Secretion by STAT3
antisense chimeric (deoxy gapped) phosphorothioate
oligonucleotides**

20 The effect of ISIS 17152 (SEQ ID. NO. 99) on IgM secretion levels was determined. STAT3 has been implicated in regulation of IgM expression (Faris, M., et al., *Immunology*, 1997, 90, 350-357). BCL1 cells were grown, treated and processed as described in Example 2.

1 X 10⁶ BCL1 cells were incubated in 12-well plates in 2 mL complete RPMI following electroporation. Supernatant was replaced at 24 hour post electroporation with fresh medium. 48 hours later, supernatants were harvested, centrifuged to remove cells, and assayed for IgM content using the OPT-EIA™ ELISA kit (Pharmingen, San Diego, CA) and capture and detecting antibodies for mouse IgM (Southern Biotechnology, Birmingham, AL).

Results are shown in Table 7. ISIS 17152 (SEQ ID NO. 99) was significantly better at reducing IgM secretion than the mismatch control.

TABLE 7

Inhibition of BCL1 IgM secretion by STAT3

Chimeric (deoxy gapped) Phosphorothioate Oligonucleotides

ISIS #	SEQ ID NO:	ASO Gene Target	Dose	% IgM Expression	% IgM Inhibition
control	---	---	---	100%	---
17152	99	3'-UTR	5 nM	34.2%	65.8%
"	"	"	15 nM	23.1%	76.9%
23177	106	control	5 nM	110.0%	---
"	"	"	15 nM	80.8%	19.2%

EXAMPLE 7: Induction of Chemokines in BCL1 cells following Treatment with STAT3 antisense chimeric (deoxy gapped) phosphorothioate oligonucleotide

The effect of ISIS 17152 (SEQ ID. NO. 99) on chemokine levels was determined. BCL1 cells were grown, treated and processed as described in Example 2. Chemokine gene expression was induced in BCL1 cells by addition of 10 M of a CpG-containing oligonucleotide to the media 16 hours following antisense oligonucleotide electroporation.

CpG-containing oligonucleotides are immune-stimulatory (Krieg, A.M., et al., *Nature*, 1995, 374, 546-549). The levels of chemokines were measured eight hours later using RNase protection assay as described in Example 2 with a mouse chemokine template set, Mck-5 (Pharmingen, San Diego, CA).

Results are shown in Table 8. ISIS 17152 (SEQ ID. NO. 99) was able to induce the expression of the chemokines, RANTES, MIP-1 and MIP-1 whereas the mismatch control had minimal effect.

TABLE 8

Induction of Chemokines in BCL1 Cells Following Treatment with STAT3 Chimeric (deoxy gapped) Phosphorothioate Oligonucleotides

ISIS #	SEQ ID NO:	ASO Gene Target	Dose	% RANTES mRNA	% MIP1a mRNA	% MIP1b mRNA
control	---	---	---	100%	100%	100%
17152	99	3'-UTR	5 nM	236%	201%	133%
"	"	"	10 nM	266%	258%	150%
"	"	"	20 nM	257%	254%	159%
23178	107	control	5 nM	96%	123%	96.5%
"	"	"	10 nM	70.2%	116%	87.1%
"	"	"	20 nM	56%	106%	73.3%

EXAMPLE 8: Effect of STAT3 Antisense Oligonucleotides in a Murine Model for Rheumatoid Arthritis

Collagen-induced arthritis (CIA) is used as a murine model for arthritis (Mussener, A., et al., *Clin. Exp. Immunol.*, 1997, 107, 485-493). Female DBA/1LacJ mice

(Jackson Laboratories, Bar Harbor, ME) between the ages of 6 and 8 weeks are used to assess the activity of STAT3 antisense oligonucleotides.

On day 0, the mice are immunized at the base of the tail with 100 µg of bovine type II collagen which is emulsified in Complete Freund's Adjuvant (CFA). On day 7, a second booster dose of collagen is administered by the same route. On day 14, the mice are injected subcutaneously with 100 µg of LPS. Oligonucleotide is administered intraperitoneally daily (10 mg/kg bolus) starting on day -3 and continuing for the duration of the study.

Weights are recorded weekly. Mice are inspected daily for the onset of CIA. Paw widths are rear ankle widths of affected and unaffected joints and are measured three times a week using a constant tension caliper. Limbs are clinically evaluated and graded on a scale from 0-4 (with 4 being the highest).

Example 9: Effect of STAT3 antisense oligonucleotides on growth of human MDA-MB231 tumors in nude mice

MDA-MB231 human breast carcinoma cells are obtained from the American Type Culture Collection (Bethesda, MD). Serially transplanted MDA-MB231 tumors are established subcutaneously in nude mice. Beginning two weeks later, STAT3 antisense oligonucleotides, in saline, are administered intravenously daily for 14 days at dosages of 60 mg/kg and 6 mg/kg. Control oligonucleotides are also administered at these doses, and a saline control is also given. Tumor growth rates are monitored for the two-week period of oligonucleotide administration. Activity of the STAT3 antisense oligonucleotides is measured by a reduction in tumor growth. A lower-dose study can also be conducted using the same oligonucleotides at 6 mg/kg and 0.6 mg/kg.

Example 10: Effect of STAT3 antisense oligonucleotides on U-87 human glioblastoma cells following subcutaneous xenografts into nude mice:

5 The U-87 human glioblastoma cell line is obtained from the ATCC (Rockville MD) and maintained in Iscove's DMEM medium supplemented with heat-inactivated 10% fetal calf serum. Nude mice are injected subcutaneously with 2×10^7 cells. Mice are injected intraperitoneally with STAT3
10 antisense oligonucleotides at dosages of either 2 mg/kg or 20 mg/kg for 21 consecutive days beginning 7 days after xenografts are implanted. Tumor volumes are measured on days 14, 21, 24, 31 and 35. Activity is measured by reduced tumor volume compared to saline or sense
15 oligonucleotide control.

Example 11: Effect of STAT3 antisense oligonucleotides on intracerebral U-87 glioblastoma xenografts into nude mice

 U-87 cells are implanted in the brains of nude mice.
20 Mice are treated via continuous intraperitoneal administration of STAT3 antisense oligonucleotides at 20 mg/kg, control sense oligonucleotide (20 mg/kg) or saline beginning on day 7 after xenograft implantation. Activity of the STAT3 antisense oligonucleotides is measured by an
25 increase in survival time compared to controls.

Example 12: Additional antisense oligonucleotides targeted to human STAT3

 An additional set of oligonucleotides targeted to SEQ
30 ID NO: 1 was designed and synthesized as chimeric oligonucleotides ("gapmers") 20 nucleotides in length, composed of a central "gap" region consisting of ten 2'-deoxynucleotides, which is flanked on both sides (5' and 3' directions) by five-nucleotide "wings." The wings are
35 composed of 2'-methoxyethyl (2'-MOE)nucleotides (shown in bold). The internucleoside (backbone) linkages are

phosphorothioate (P=S) throughout the oligonucleotide. All 2'-MOE cytosines and 2'-deoxy cytosines were 5-methyl-cytosines. These oligonucleotide sequences are shown in Table 9.

5

TABLE 9:

Nucleotide Sequences of Additional Chimeric (deoxy gapped) Phosphorothioate Oligonucleotides targeted to Human STAT3

ISIS NO.	NUCLEOTIDE SEQUENCE ¹ (5' -> 3')	TARGET GENE NUCLEOTIDE CO- ORDINATES ²	GENE TARGET REGION	SEQ ID NO:
113169	ATGTGATTCTTTGCTGGCCG	357	5' UTR	108
113170	AGCTGATTCCATTGGGCCAT	221	AUG	109
113171	CCAGGAGATTATGAAACACC	385	Coding	110
113172	ACCGTGTGTCAAGCTGCTGT	241	Coding	111
113173	CCATTGGGAAGCTGTCACTG	286	Coding	112
113174	TGTGATTCTTTGCTGGCCGC	356	Coding	113
113175	GCGGCTATACTGCTGGTCAA	411	Coding	114
113176	GCTCCAGCATCTGCTGCTTC	637	Coding	115
113177	GATTCTTCCCACAGGCACCG	539	Coding	116
113178	TGATTCTTCCCACAGGCACC	540	Coding	117
113179	ATCCTGAAGGTGCTGCTCCA	651	Coding	118
113180	CGGACATCCTGAAGGTGCTG	656	Coding	119
113181	CCCGCCAGCTCACTCACGAT	869	Coding	120
113182	AGTCAGCCAGCTCCTCGTCC	928	Coding	121
113183	CCAGTCAGCCAGCTCCTCGT	930	Coding	122
113184	CGCCTCTTCCAGTCAGCCAG	938	Coding	123
113185	GGCCGGTGCTGTACAATGGG	1109	Coding	124
113186	ATCCTCTCCTCCAGCATCGG	1127	Coding	125

ISIS NO.	NUCLEOTIDE SEQUENCE ¹ (5' -> 3')	TARGET GENE NUCLEOTIDE CO- ORDINATES ²	GENE TARGET REGION	SEQ ID NO:
113187	CCGCTCCACCACAAAGGCAC	1176	Coding	126
113188	CGTCCCCAGAGTCTTTGTCA	1324	Coding	127
113189	TTGTGTTTGTGCCCAGAATG	1375	Coding	128
113190	GCTCGGCCCCCATTCACACA	1472	Coding	129
113191	AGGCATTGTCATCTGACAG	1621	Coding	130
113192	CTTGGGATTGTTGGTCAGCA	1665	Coding	131
113193	CTCGGCCACTTGGTCCCAGG	1719	Coding	132
113194	CCCCGCTTGGTGGTGGACGA	1757	Coding	133
113195	CCCCCGCTTGGTGGTGGACG	1758	Coding	134
113196	GGAGAAGCCCTTGCCAGCCA	1881	Coding	135
113197	TTCATTCCAAAGGGCCAAGA	1947	Coding	136
113198	CCCGCTCCTTGCTGATGAAA	1981	Coding	137
113199	GTGCTCAAGATGGCCCGCTC	2000	Coding	138
113200	CCCAAGTGAAAGTGACGCCT	2071	Coding	139
113201	ACCCAAGTGAAAGTGACGCC	2072	Coding	140
113202	CCGAATGCCTCCTCCTTGGG	2252	Coding	141
113203	GCCGACAATACTTCCCGAAT	2266	Coding	142
113204	GATGCTCCTGGCTCTCTGGC	2284	Coding	143
113205	TCAATGAATCTAAAGCGCGG	2404	Coding	144
113206	GACTCAAAGTGCCTCCTGTC	2462	Coding	145
113207	ATC ATCACCACATTCACTCATT	2710	3' UTR	146
113208	AAAAGTGCCCAGATTGC	2682	3' UTR	147
113209	AAAAGTGCCCAGATTGCTCA	2679	3' UTR	148
113210	TAAAAGTGCCCAGATTGCTC	2680	3' UTR	149

ISIS NO.	NUCLEOTIDE SEQUENCE ¹ (5' -> 3')	TARGET GENE NUCLEOTIDE CO- ORDINATES ²	GENE TARGET REGION	SEQ ID NO:
113211	AAGCAGATCACCCACATTCA	2716	3' UTR	150

These oligonucleotides were screened by Northern blot analysis in U266 cells at an oligonucleotide concentration of 2.5 μ M. U266 human myeloma cell lines (originally
 5 obtained from American Type Culture Collection) were maintained in RPMI 1640 medium supplemented with 10% fetal calf serum. Cells (15×10^6 cells in PBS) were transfected with oligonucleotides at 200V with a single 6-millisecond pulse using a BTX Electro Square Porator T820 (Genetronics,
 10 San Diego CA). The cells were incubated for 24 hours before RNA extraction.

Total cellular RNA was isolated using the Rneasy kit (Qiagen, Santa Clarita, CA). Northern blotting was performed on 15 μ g of RNA using a cDNA probe prepared from MB-MDA 468
 15 RNA by standard RT-PCR followed by a nested primer reaction. Signals were quantitated using a Molecular Dynamics Phosphorimager.

Results for selected compounds (expressed as percent of control mRNA expression and percent inhibition of mRNA
 20 expression) are shown in Table 10.

TABLE 10

Inhibition of Human STAT3 mRNA expression in U266 Cells by Chimeric (deoxy gapped) Phosphorothioate Oligonucleotides

ISIS No:	SEQ ID NO:	GENE TARGET REGION	% mRNA EXPRESSION	% mRNA INHIBITION
None	--	--	100	--
17148	95	Coding	95.1	4.9

17152	99	3' UTR	82.5	17.5
113170	109	AUG	89.6	10.4
113171	110	Coding	110.2	--
113172	111	Coding	96.1	3.9
113173	112	Coding	119	--
113175	114	Coding	75.8	24.2
113176	115	Coding	72.3	27.7
113178	117	Coding	143.9	--
113181	120	Coding	105.4	--
113184	123	Coding	104.3	--
113187	126	Coding	55.9	44.1
113189	128	Coding	163.9	--
113199	139	Coding	64.4	35.6
113207	146	3' UTR	123.6	--
113209	148	3' UTR	71.4	28.6
113210	149	3' UTR	72.2	27.8
113211	150	3' UTR	116.5	--

Dose-response experiments were conducted for ISIS 113176, 129987, 113187, 129991, 113209, 129995, 113210 and 129999 as well as ISIS 17148 and the mouse STAT3 oligo ISIS 114054. Results are shown in Table 11.

Table 11

Percent inhibition of human STAT3 mRNA expression with
antisense oligonucleotides- dose response

ISIS #	SEQ ID NO:	Percent inhibition of STAT3 expression		
		Oligo concentration		
		2.5 μ M	5 μ M	10 μ M
17148	95	8	54	60
114054		4	17	15
113176		33	67	79
129987		5	5	29
113187		44	56	75
129991		21	22	26
113209		43	54	73
129995		5	32	25
113210		36	50	76
129999		31	8	--

5

ISIS 17148, 113176, 113187, 113209 and 113210 were shown to reduce STAT3 expression by over 50% at one or more oligonucleotide concentrations. These compounds are therefore preferred.

10 **Example 13: Antisense inhibition of STAT3 causes apoptotic cell death in mouse melanoma cells**

Mouse B16 melanoma cells were grown in RPMI 1640 (Life Technologies, Inc., Grand Island, NY) medium

supplemented with 10% fetal bovine serum, 2 mM L-glutamine, 1 mM sodium pyruvate, 1% MEM nonessential amino acids and 100 IU/ml penicillin/streptomycin.

Cells were treated with ISIS 17152, targeted to mouse
5 STAT3, or the 3-base mismatch control, ISIS 28084
(AAAAAGAGGCCTGATTGCCC; SEQ ID NO: 151). Cells were
transfected with oligonucleotide using LipofectAMINE PLUSJ
reagent (GibcoBRL). Oligonucleotide was pre-complexed with
LipofectAMINE PLUSJ by adding the oligonucleotide to 100 µl
10 serum-free RPMI 1640 medium, then 6 µl LipofectAMINE PLUSJ
reagent was added, the sample was mixed well and incubated
for 15 minutes at room temperature. An additional 4 µl of
LipofectAMINE PLUSJ reagent was diluted to 100 µl in serum-
free RPMI. This diluted LipofectAMINE PLUSJ was mixed with
15 the pre-complexed oligonucleotide/LipofectAMINE PLUSJ
mixture and incubated for 15 minutes at room temperature.
800 µl of serum-free RPMI 1640 was added, and the resulting
oligonucleotide-LipofectAMINE PLUSJ-medium mixture
(approximately 1 ml) was added to cells in a 6-well plate.
20 After 3 hours incubation, 1 ml of RPMI 1640 supplemented
with 20% fetal bovine serum was added. Oligonucleotide
concentrations were 200 nM or 300 nM.

24 hours after transfection, cells were counted to
determine the effect of antisense treatment on cell death.
25 Cells were harvested at 24 hours post transfection for
western blot analysis and at 48 hours post-transfection for
Annexin-V staining for apoptosis.

Effects of oligonucleotide on cell number are shown in
Table 12.

Table 12

Effect of antisense inhibition of STAT3 on cell number

Expt	200 nM		300 nM	
	ISIS 28084 (3 mismatch)	ISIS 17152	ISIS 28084 (3 mismatch)	ISIS 17152
1	10.2×10^5	3.8×10^5		
2	5.0×10^5	6.8×10^5	9.1×10^5	3.5×10^5
3	3.5×10^5	1.8×10^5	3.3×10^5	2.2×10^5

Thus treatment with STAT3 antisense oligonucleotide increased cell death (decreased cell number).

Apoptosis in B16 cells was measured by staining with Annexin V-PE (Clontech) and flow cytometry analysis 48 hours after antisense treatment. Positive staining for Annexin-V indicates apoptosis is occurring. Mock-transfected cells and control oligonucleotide-treated cell cultures had 11.37% and 10.15% of cells staining positive for Annexin-V. In contrast, ISIS 17152-treated cells were 29.84% positive for Annexin-V, indicating a nearly threefold increase in apoptotic cells. It should be noted that in general, the percent of apoptosis in B16 cells is likely to have been underestimated since detached dead cells are washed off in processing.

Western blot analysis was done on cells 24 hours after antisense treatment, using an anti-STAT3 antibody (K15, Santa Cruz Biotechnology, Santa Cruz, CA). ISIS 17152 at 200nM or 300 nM significantly reduced STAT3 protein production in B16 cells.

Example 14: Effect of STAT3 antisense oligonucleotides on melanoma tumors

Six-week-old female C57BL mice were purchased from the National Cancer Center (Frederick MD) and maintained under approved conditions. Mice were shaved in the left

flank area and injected subcutaneously with 2×10^5 B16 melanoma cells in 100 μ l of PBS. After 7-10 days, B16 tumors with a diameter of 3-6 mm were established. Tumor volume was calculated according to the formula $V = 0.52 \times a^2 \times b$ (a, smallest superficial diameter; b, largest superficial diameter).

Beginning two weeks later, STAT3 antisense oligonucleotides, in saline, are administered intravenously daily for 14 days at dosages of 60 mg/kg and 6 mg/kg. Control oligonucleotides are also administered at these doses, and a saline control is also given. Tumor growth rates are monitored for the two-week period of oligonucleotide administration. Activity of the STAT3 antisense oligonucleotides is measured by a reduction in tumor growth. A lower-dose study can also be conducted using the same oligonucleotides at 6 mg/kg and 0.6 mg/kg.

Example 15: Effect of STAT3 antisense oligonucleotides on leukemic large granular lymphocytes (LGL)

LGL leukemia is a lymphoproliferative disease with autoimmune features and LGL cells are known to be insensitive to Fas-dependent cell death despite high levels of Fas and FasL expression. (Lamy et al., *Blood*, 1998, 92, 4771-7). STAT3 antisense oligonucleotides were tested for their ability to sensitize LGL cells to the apoptotic signal in these cells.

LGL leukemic cells were obtained from patients who met the clinical criteria of T cell (CD3+) LGL leukemia with increased LGL counts and clonal TCR gene rearrangements. All patients had chronic disease not requiring treatment at the time of analysis. Purified leukemic LGL cells were placed in 24-well plates at a concentration of 2×10^6 /0.5mL of complete medium (RPMI-1640 medium supplemented with 10% fetal bovine serum, 2 mM L-glutamine, 10 U/mL penicillin, and 100 ug/mL streptomycin,

all from Gibco Life Technologies, Gaithersburg, MD). Cells were incubated with either ISIS 17148 antisense oligonucleotide (SEQ ID NO: 95) or the control, ISIS 16094 (SEQ ID NO: 152). Antisense oligonucleotide delivery to LGL leukemic cells was by passive uptake and no transfection reagents were included in the reaction.

Both ISIS 17148 and ISIS 16094 are 20 nucleotides in length, composed of a central "gap" region consisting of ten 2'-deoxynucleotides, which is flanked on both sides (5' and 3' directions) by five-nucleotide "wings." The wings are composed of 2'-methoxyethyl (2'-MOE)nucleotides. The internucleoside (backbone) linkages are phosphorothioate (P=S) throughout the oligonucleotide. All 2'-MOE cytosines and 2'-deoxy cytosines were 5-methyl-cytosines.

Extracts of LGL cells treated with antisense oligonucleotides (1 uM dosing for ISIS 17148 and the control) from three patients were obtained and assayed for STAT3 protein levels by Western blot. Sensitization of the LGL cells to Fas-mediated apoptosis was also measured by flow cytometry in cells treated with antisense oligonucleotides at doses of 1, 2 and 5 uM. By Western analysis, a reduction in STAT3 protein levels ranged from 25 to 45%. Sensitivity to Fas-mediated apoptosis was also significantly increased in the antisense treated cells and was dose dependent. Measurements of percent specific apoptosis in duplicate reactions revealed an increase in apoptosis from 5% in untreated cells to levels of 6, 17 and 24% in antisense-treated cells at 1, 2, and 5 uM, respectively. Levels of apoptosis in control oligonucleotide treated cells remained at 6% at all doses.

Example 16**Induction of apoptosis in the human myeloma cell line U266 following Stat3 antisense oligonucleotide treatment**Methods5 **Cell culture**

U266 cells (ATCC, Bethesda, MD) were cultured in RPMI 1640 medium supplemented with 10% heat-inactivated fetal bovine serum (Sigma Chemical Company, St. Louis, MO), 10 mM Hepes, pH 7.2, 50 M 2-ME, 2mM L-glutamine, 100 U/ml penicillin, and 100 g/ml streptomycin (Gibco, Grand Island, NY).

Oligonucleotide Synthesis and Transfection of U266 Cells

2'-O-methoxyethylribose modified phosphorothioate oligonucleotides were synthesized on an automated DNA synthesizer (Applied Biosystems model 380B), as described above. Chimeric oligonucleotides were employed in these studies; the chimeric oligonucleotides contain 2'-O-methoxyethyl modified residues flanking a 2'-deoxynucleotide/phosphorothioate region (gap) that supports RNase H activation. Oligonucleotides were analyzed by capillary gel electrophoresis and judged to be at least 85% full-length material. U266 (1×10^7 cells in PBS) were transfected with oligonucleotides by electroporation, at 175V, 1000 μ F using a BTX Electro Cell Manipulator 600 (Genetronics, San Diego, CA).

Flow Cytometric Analysis of Apoptosis

30 10×10^6 U266 cells were electroporated with oligonucleotides and cultured for 48 hours before analysis

of phosphatidylserine expression was performed as a measure of apoptosis using the Annexin-V staining kit (Clontech, Palo Alto, CA) according to the manufacturer's instructions. Briefly, the cells were resuspended in 0.2 mL of staining buffer (10 mM HEPES, pH 7.4, 140 mM NaCl, 5 mM CaCl₂) and 10 µL of propidium iodide (50 µg/ml) and 5 µL of Annexin V reagent were added at 4°C for 10 minutes. The samples were then diluted with FACSFlow buffer and analyzed on a Becton Dickinson FACScan (Mountain View, CA).

10

Results

Antisense inhibition of STAT3 induces apoptosis of U266 multiple myeloma cells.

15 In order to examine the importance of STAT3 expression in multiple myeloma cells, a series of 20mer STAT3 antisense oligonucleotides were designed and synthesized, using phosphorothioate chemistry and incorporating 2'-O-methoxyethyl modifications to improve hybridization affinity and nuclease resistance. Screens performed in U266 MM cells identified several sequences that optimally inhibited STAT3 mRNA expression, as determined by Northern blotting. Two antisense oligonucleotides, ISIS 17148 (SEQ ID NO: 95) and ISIS 25 113176 (SEQ ID NO: 115) were found to potently inhibit STAT3 mRNA expression in U266 cells following electroporation in a dose-dependent fashion. Control oligonucleotide containing 5 mismatched bases within the 2'-deoxyphosphorothioate central gap region failed to 30 inhibit STAT3 mRNA expression, demonstrating a hybridization-dependent mechanism of target reduction.

Further characterization of the STAT3 antisense oligonucleotides was performed, using Western blotting of nuclear extracts from U266 cells to evaluate STAT3 protein reduction following oligonucleotide transfection. The 35

STAT3 antisense oligonucleotides were found to dose-dependently inhibit STAT3 protein expression in a manner that correlated well with the mRNA inhibition, when evaluated 48 hours after transfection. The five base mismatch control oligonucleotide at the highest dose did not show any effect, further suggesting an antisense mechanism of action.

Previously published data using a dominant negative expression vector encoding STAT3 lacking an intact transactivation domain suggested that STAT3 was a survival factor for MM cells (Catlett-Falcone et al., Immunity 10: 105, 1999). Changes in the proliferative index of STAT3 antisense transfected U266 cells as well as reduced viability in culture following STAT3 antisense transfection led us to determine whether reduction of wild type STAT3 protein would also induce an apoptotic response. Transfection of U266 cells with either ISIS 17148 or 113176 was found to result in increased levels of annexin V staining as assessed by flow cytometry. This effect contrasted to that of control oligonucleotides, either an antisense oligonucleotide targeted to a gene not expressed by U266 cells or the 5 base mismatch control oligonucleotide. These data further support an anti-apoptotic role for STAT3 in multiple myeloma.

Example 17

Design of phenotypic assays and *in vivo* studies for the use of STAT3 inhibitors

Phenotypic assays

Once STAT3 inhibitors have been identified by the methods disclosed herein, the compounds are further investigated in one or more phenotypic assays, each having measurable endpoints predictive of efficacy in the treatment of a particular disease state or condition. Phenotypic assays, kits and reagents for their use are well

known to those skilled in the art and are herein used to investigate the role and/or association of STAT3 in health and disease. Representative phenotypic assays, which can be purchased from any one of several commercial vendors, include those for determining cell viability, cytotoxicity, proliferation or cell survival (Molecular Probes, Eugene, OR; PerkinElmer, Boston, MA), protein-based assays including enzymatic assays (Panvera, LLC, Madison, WI; BD Biosciences, Franklin Lakes, NJ; Oncogene Research Products, San Diego, CA), cell regulation, signal transduction, inflammation, oxidative processes and apoptosis (Assay Designs Inc., Ann Arbor, MI), triglyceride accumulation (Sigma-Aldrich, St. Louis, MO), angiogenesis assays, tube formation assays, cytokine and hormone assays and metabolic assays (Chemicon International Inc., Temecula, CA; Amersham Biosciences, Piscataway, NJ).

In one non-limiting example, cells determined to be appropriate for a particular phenotypic assay (i.e., MCF-7 cells selected for breast cancer studies; adipocytes for obesity studies) are treated with STAT3 inhibitors identified from the *in vitro* studies as well as control compounds at optimal concentrations which are determined by the methods described above. At the end of the treatment period, treated and untreated cells are analyzed by one or more methods specific for the assay to determine phenotypic outcomes and endpoints.

Phenotypic endpoints include changes in cell morphology over time or treatment dose as well as changes in levels of cellular components such as proteins, lipids, nucleic acids, hormones, saccharides or metals. Measurements of cellular status which include pH, stage of the cell cycle, intake or excretion of biological indicators by the cell, are also endpoints of interest. Analysis of the genotype of the cell (measurement of the expression of one or more of the genes of the cell) after treatment is also used as an indicator of the efficacy or potency of STAT3 inhibitors. Hallmark genes, or those

genes suspected to be associated with a specific disease state, condition, or phenotype, are measured in both treated and untreated cells.

5 **Example 18**

Antisense inhibition of human STAT3 by chimeric phosphorothioate oligonucleotides having 2'-MOE wings and a deoxy gap

10 In accordance with the present invention, an additional series of oligonucleotides was designed to target different regions of the human STAT 3, using published sequences (GenBank accession number L29277, incorporated herein as SEQ ID NO: 1, the complement of nucleotides 4189213 to 4263636 of the sequence with the
15 GenBank accession number NT_010755.13, incorporated herein as SEQ ID NO: 153 and GenBank accession number NM_139276.1, incorporated herein as SEQ ID NO: 154). The oligonucleotides are shown in Table 13. "Target site" indicates the first (5'-most) nucleotide number on the
20 particular target sequence to which the oligonucleotide binds. All compounds in Table 13 are chimeric oligonucleotides ("gapmers") 20 nucleotides in length, composed of a central "gap" region consisting of ten 2'-deoxynucleotides, which is flanked on both sides (5' and 3'
25 directions) by five-nucleotide "wings". The wings are composed of 2'-methoxyethyl (2'-MOE)nucleotides. The internucleoside (backbone) linkages are phosphorothioate (P=S) throughout the oligonucleotide. All cytidine residues are 5-methylcytidines.

30 The compounds were analyzed for their effect on STAT3 mRNA levels in A549 cells. The human lung carcinoma cell line A549 was obtained from the American Type Culture Collection (ATCC) (Manassas, VA). A549 cells were routinely cultured in DMEM basal media (Invitrogen
35 Corporation, Carlsbad, CA) supplemented with 10% fetal calf serum (Invitrogen Corporation, Carlsbad, CA), 100 units/mL

penicillin, and 100 ug/mL streptomycin (Invitrogen Corporation, Carlsbad, CA). Cells were routinely passaged by trypsinization and dilution when they reached 90% confluence.

5 ISIS 18078 was used as a control oligonucleotide and was used at 75nM. ISIS 18078 (GTGCGCGCGAGCCCGAAATC, SEQ ID NO: 155) is an chimeric oligonucleotide ("gapmers") 20 nucleotides in length, composed of a central "gap" region consisting of nine 2'-deoxynucleotides, which is flanked on
10 both sides (5' and 3' directions) by five-nucleotide and six-nucleotide "wings", respectively. The wings are composed of 2'-methoxyethyl (2'-MOE)nucleotides. The internucleoside (backbone) linkages are phosphorothioate (P=S) throughout the oligonucleotide. All cytidine
15 residues are 5-methylcytidines.

When cells reached 65-75% confluency, they were treated with oligonucleotide. For cells grown in 96-well plates, wells were washed once with 100 L OPTI-MEM-1 reduced-serum medium (Invitrogen Corporation, Carlsbad, CA)
20 and then treated with 130 L of OPTI-MEM-1 containing 3.75 g/mL LIPOFECTIN (Invitrogen Corporation, Carlsbad, CA) and 75 nM of the compounds in Table 13. Cells were treated and data were obtained in duplicate. Untreated cells served as controls. After 4-7 hours of treatment at 37°C, the medium
25 was replaced with fresh medium. Cells were harvested 16-24 hours after oligonucleotide treatment. STAT3 mRNA levels in A549 cells were quantitated by real-time PCR as described by other methods herein.

Probes and primers to human STAT3 were designed to
30 hybridize to a human STAT3 sequence, using published sequence information (incorporated herein as SEQ ID NO: 1). For STAT 3 the PCR primers were:
forward primer: ACATGCCACTTTGGTGTTCATAA (SEQ ID NO: 156)
reverse primer: TCTTCGTAGATTGTGCTGATAGAGAAC (SEQ ID NO:
35 157) and the PCR probe was: FAM-CAGTATAGCCGCTTCCTGCAAGAGTCGAA -TAMRA (SEQ ID NO: 158) where FAM is the fluorescent reporter dye and TAMRA is the

quencher dye. This primer probe set is referred to as PPS 199. Gene target quantities obtained by real time RT-PCR are normalized by quantifying total RNA using RiboGreen™ (Molecular Probes, Inc. Eugene, OR). In this assay, 170 µL of RiboGreen™ working reagent (RiboGreen™ reagent diluted 1:350 in 10mM Tris-HCl, 1 mM EDTA, pH 7.5) is pipetted into a 96-well plate containing 30 µL purified, cellular RNA. The plate is read in a CytoFluor 4000 (PE Applied Biosystems) with excitation at 485nm and emission at 530nm.

The results of the antisense oligonucleotide treatments are the average of 2 experiments and are shown in Table 13. Data are expressed as percent inhibition relative to untreated control cells.

Table 13

Inhibition of human STAT 3 mRNA levels by chimeric phosphorothioate oligonucleotides having 2'-MOE wings and a deoxy gap

Isis #	Region	Target Seq ID No	Target Site	Sequence	% Inhib	Seq ID No
337245	intron	153	6814	AGCCTCTGCACCCTCATGTT	77	159
337246	intron	153	6868	CTCCTAAATTAAGAACTTCT	37	160
337247	intron	153	14801	TTTTGCATGATGTAACCACT	87	161
337248	intron	153	34820	TATTGAAAATTATCTAATTC	0	162
337249	coding	153	40369	TTGGGCCATCCTGCTAAAT	48	163
337250	exon:intron	153	50156	ATTCACCTGCCTCCTTGACT	51	164
337251	intron:exon	153	51124	ATGCCCTTACTCTCCGCATC	74	165
337252	exon:intron	153	59140	CTGAACCTACCCTCTGAGAG	60	166
337253	exon:intron	153	64176	AAATGCGGACCCAAGAGTTT	49	167
337254	5'UTR	1	56	CTTGTTCCCTCGGCTGCGAC	57	168
337255	5'UTR	1	79	GCCTGTCCAGGATCCGGTTG	75	169
337256	5'UTR	1	126	GAAGGGCCTCTCCGAGCCGA	67	170
337257	5'UTR	1	148	GGCGGCGAGGCTCCCTCAGG	80	171
337258	5'UTR	1	193	TCCGGCAGAGGCCGAGAGGC	56	172
337259	5'UTR	154	225	CCATCCTGCTAAATCAGGG	58	173
337260	5'UTR	154	233	CCATTGGGCCATCCTGCTAA	62	174
337261	coding	1	235	TGTCAAGCTGCTGTAGCTGA	79	175
337262	coding	1	299	AACTGCCGAGCTCCATTGG	74	176
337263	coding	1	326	TCTTGACTCTCAATCCAAGG	79	177
337264	coding	1	339	CGCATATGCCCAATCTTGAC	81	178
337265	coding	1	426	CGACTCTTGACGGAAGCGGC	92	179
337266	coding	1	453	TCGTAGATTGTGCTGATAGA	61	180
337267	coding	1	470	AGAAACTGCTTGATTCTTCG	62	181
337268	coding	1	484	GATACCTGCTCTGAAGAAAC	75	182

337269	coding	1	491	TTCTCAAGATACCTGCTCTG	74	183
337270	coding	1	496	TTGGCTTCTCAAGATACCTG	89	184
337271	coding	1	541	GTGATTCTTCCCACAGGCAC	85	185
337272	coding	1	629	ATCTGCTGCTTCTCCGTAC	74	186
337273	coding	1	634	CCAGCATCTGCTGCTTCTCC	73	187
337274	coding	1	647	TGAAGGTGCTGCTCCAGCAT	74	188
337275	coding	1	683	TTCTGTTCTAGATCCTGCAC	82	189
337276	coding	1	708	CTGGAGATTCTCTACCACTT	91	190
337277	coding	1	716	AAGTCATCCTGGAGATTCTC	79	191
337278	coding	1	721	AATCAAAGTCATCCTGGAGA	69	192
337279	coding	1	726	GTTGAAATCAAAGTCATCCT	78	193
337280	coding	1	731	TTATAGTTGAAATCAAAGTC	45	194
337281	coding	1	736	GGGTTTTATAGTTGAAATCA	16	195
337282	coding	1	741	CTTGAGGGTTTTATAGTTGA	58	196
337283	coding	1	746	TGACTCTTGAGGGTTTTATA	71	197
337284	coding	1	751	CTCCTTGACTCTTGAGGGTT	91	198
337285	coding	1	756	CATGTCCTTGACTCTTGA	78	199
337286	coding	1	768	ATTGAGATCTGCATGCTCTC	77	200
337287	coding	1	779	TGGTTGTTTCCATTCAGATC	82	201
337288	coding	1	790	TGGTCACTGACTGGTTGTTT	84	202
337289	coding	1	812	TCCAGCTGCTGCATCTTCTG	83	203
337290	coding	1	822	GAGCATCTGTTCCAGCTGCT	80	204
337291	coding	1	848	CTTCTCCGCATCTGGTCCAG	66	205
337292	coding	1	899	TTCTGCACGTACTCCATCGC	81	206
337293	coding	1	925	CAGCCAGCTCCTCGTCCGTG	92	207
337294	coding	1	935	CTCTTCCAGTCAGCCAGCTC	75	208
337295	coding	1	941	TGCCCGCTCTTCCAGTCAGC	82	209
337296	coding	1	999	CCAGTTTTCTAGCCGATCTA	80	210
337297	coding	1	1006	ACGTTATCCAGTTTTCTAGC	72	211
337298	coding	1	1025	AGTTGAGATTCTGCTAATGA	74	212
337299	coding	1	1030	TCTGAAGTTGAGATTCTGCT	80	213
337300	coding	1	1085	CCTTTGTAGGAACTTTTTTG	23	214
337301	coding	1	1162	AGGCACTTTTCATTAAGTTT	73	215
337302	coding	1	1262	TTGACCAGCAACCTGACTTT	61	216
337303	coding	1	1286	AGCTGATAATTCAACTCAGG	85	217
337304	coding	1	1291	TTTTAAGCTGATAATTCAAC	15	218
337305	coding	1	1297	CTTTAATTTTAAGCTGATAA	25	219
337306	coding	1	1302	GCACACTTTAATTTTAAGCT	77	220
337307	coding	1	1307	TCAATGCACACTTTAATTTT	53	221
337308	coding	1	1364	CCCAGAATGTTAAATTTCCG	70	222
337309	coding	1	1414	AGAGGCTGCCGTTGTTGGAT	73	223
337310	coding	1	1433	AAGTGTTTGAATTCTGCAGA	73	224
337311	coding	1	1452	TCTCTGCTCCCTCAGGGTCA	61	225
337312	coding	1	1517	ATCAGGTGCAGCTCCTCAGT	78	226
337313	coding	1	1522	AGGTGATCAGGTGCAGCTCC	61	227
337314	coding	1	1527	CTCAAAGGTGATCAGGTGCA	75	228
337315	coding	154	1571	GAGGCCTTGGTGATACACCT	46	229
337316	coding	154	1579	TCAATCTTGAGGCCTTGGTG	59	230
337317	coding	154	1584	CTAGGTCAATCTTGAGGCCT	55	231
337318	coding	1	1569	GGTCTCTAGGTCAATCTTGA	74	232
337319	coding	1	1577	AAGGAGTGGGTCTCTAGGTC	38	233
337320	coding	154	1602	CTGGCAAGGAGTGGGTCTCT	74	234
337321	coding	154	1609	ACCACAACCTGGCAAGGAGTG	80	235
337322	coding	1	1609	CTGACAGATGTTGGAGATC	69	236
337323	coding	1	1614	TGGCATCTGACAGATGTTGG	79	237
337324	coding	1	1619	GCATTTGGCATCTGACAGAT	79	238
337325	coding	1	1667	TTCTTGGGATTGTTGGTCAG	75	239
337326	coding	1	1778	GTCAGCTGCTCGATGCTCAG	78	240
337327	coding	154	1823	TCCAAGAGTTTCTCTGCCA	84	241

337328	coding	1	1838	CATGTGATCTGACACCCTGA	85	242
337329	coding	1	1843	TAGCCCATGTGATCTGACAC	88	243
337330	coding	154	1885	GCCATGTTTCTTTGCAAAA	59	244
337331	coding	1	1873	CCTTGCCAGCCATGTTTCT	88	245
337332	coding	1	1878	GAAGCCCTTGCCAGCCATGT	91	246
337333	coding	154	1903	AAGGAGAAGCCCTTGCCAGC	90	247
337334	coding	154	1908	CCCAGAAGGAGAAGCCCTTG	85	248
337335	coding	154	1918	TCCAGCCAGACCCAGAAGGA	86	249
337336	coding	1	2048	TCTTTGCTGCTTTCAGTGAA	79	250
337337	coding	1	2144	ATGTTGTTTCAGCTGCTGCTT	76	251
337338	coding	1	2149	ATGACATGTTGTTTCAGCTGC	80	252
337339	coding	1	2154	AGCAAATGACATGTTGTTCA	84	253
337340	coding	1	2159	ATTTTCAGCAAATGACATGTT	72	254
337341	coding	1	2164	TGATGATTTTCAGCAAATGAC	74	255
337342	coding	1	2174	TTATAGCCCATGATGATTTC	81	256
337343	coding	1	2179	TGATCTTATAGCCCATGATG	84	257
337344	coding	1	2184	ATCCATGATCTTATAGCCCA	90	258
337345	coding	1	2190	GTAGCATCCATGATCTTAT	86	259
337346	coding	1	2232	AATGTCAGGATAGAGATAGA	55	260
337347	coding	1	2246	GCCTCCTCCTTGGAATGTC	88	261
337348	coding	154	2273	TCCGAATGCCTCCTCCTTGG	92	262
337349	coding	154	2278	TACTTTCCGAATGCCTCCTC	65	263
337350	coding	154	2283	GACAATACTTTCCGAATGCC	84	264
337351	coding	1	2303	CTACCTGGGTCAGCTTCAGG	74	265
337352	coding	1	2333	ATAAACTTGGTCTTCAGGTA	80	266
337353	coding	1	2351	GTCGTTGGTGTACACAGAT	81	267
337354	coding	1	2356	TGCAGGTCGTTGGTGTACA	62	268
337355	coding	1	2361	ATTGCTGCAGGTCGTTGGTG	61	269
337356	coding	1	2366	ATGGTATTGCTGCAGGTCGT	75	270
337357	coding	1	2371	GGTCAATGGTATTGCTGCAG	71	271
337358	coding	1	2381	GACATCGGCAGGTCAATGGT	77	272
337359	coding	154	2423	CAATGAATCTAAAGTCCGGG	57	273
337360	coding	154	2428	TGCATCAATGAATCTAAAGT	71	274
337361	coding	1	2413	CAAACATGCATCAATGAATCT	61	275
337362	coding	1	2418	ATTTCCAAACTGCATCAATG	69	276
337363	coding	1	2456	AACTGCCCTCCTGCTGAGGG	63	277
337364	coding	1	2469	GGTGAGGGACTCAAACCGCC	70	278
337365	3'UTR	1	2550	CAGTCGTATCTTCTGCAGC	84	279
337366	3'UTR	1	2658	AGATAGCAGAAGTAGGAGAT	66	280
337367	3'UTR	1	2678	AAAGTGCCAGATTGCTCAA	82	281
337368	3'UTR	1	2684	TTTTTAAAGTGCCAGATT	59	282
337369	3'UTR	1	2713	CAGATCACCCACATTCATC	88	283
337370	3'UTR	1	2729	TGCATTTAGATAAAAGCAGA	78	284
337371	3'UTR	1	2744	GAACACATCCTTATTTGCAT	76	285
337372	3'UTR	1	2759	ATCATGGGTCTCAGAGAACA	88	286
337373	3'UTR	154	2790	CACATCCCTGATCATGGGT	70	287
337374	3'UTR	154	2826	AGACATTTCTTTTCTCCC	67	288
337375	3'UTR	154	2908	ACCAGGAGGCACTTGCTTAA	89	289
337376	3'UTR	154	2914	GCAGGCACCAGGAGGCACTT	83	290
337377	3'UTR	154	2941	GCTTACAGAAACAGGCAGAA	78	291
337378	3'UTR	154	2959	AGGTGGCTGTGGCATTGTC	16	292
337379	3'UTR	154	2971	GTATGTAGCTATAGGTGCC	71	293
337380	3'UTR	154	2983	GCAATGCCAGGAGTATGTAG	83	294
337381	3'UTR	154	2992	TTAAAAAGTGCAATGCCAGG	86	295
337382	3'UTR	154	3032	GGCTTAGATAGTCCTATCTT	84	296
337383	3'UTR	154	3047	TAAAAAGAAACCTAGGGCTT	81	297
337384	3'UTR	154	3108	ATACAGAAAGGCTATGCTGA	89	298
337385	3'UTR	154	3121	TTAAGTTTCTTAAATACAGA	70	299

As shown in Table 13, SEQ ID Nos 159, 161, 165, 166, 169, 170, 171, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 197, 5 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 215, 216, 217, 220, 222, 223, 224, 225, 226, 227, 228, 232, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 261, 262, 263, 264, 265, 266, 267, 10 268, 269, 270, 271, 272, 274, 275, 276, 277, 278, 279, 280, 281, 283, 284, 285, 286, 287, 288, 289, 290, 291, 293, 294, 295, 296, 297, 298 and 299 inhibited human STAT3 expression at least 60%.

15 Example 19

Chimeric phosphorothioate oligonucleotides targeted to human STAT3 having 2'-MOE wings and a deoxy gap

In accordance with the present invention, an additional series of oligonucleotides was designed to 20 target different regions of the human STAT 3, using published sequences (GenBank accession number L29277, incorporated herein as SEQ ID NO: 1, GenBank accession number NM_139276.1, incorporated herein as SEQ ID NO: 154). The oligonucleotides are shown in Table 14. "Target site" 25 indicates the first (5'-most) nucleotide number on the particular target sequence to which the oligonucleotide binds. All compounds in Table 14 are chimeric oligonucleotides ("gapmers") 20 nucleotides in length, composed of a central "gap" region consisting of ten 2'-deoxynucleotides, which is flanked on both sides (5' and 3' 30 directions) by five-nucleotide "wings". The wings are composed of 2'-methoxyethyl (2'-MOE)nucleotides. The internucleoside (backbone) linkages are phosphorothioate (P=S) throughout the oligonucleotide. All cytidine 35 residues are 5-methylcytidines.

Table 14

Chimeric phosphorothioate oligonucleotides targeted to
human STAT3 having 2'-MOE wings and a deoxy gap

5

Isis #	Region	Target Seq ID No	Target Site	Sequence	Seq ID No
345752	coding	1	631	GCATCTGCTGCTTCTCCGTC	300
345753	coding	1	633	CAGCATCTGCTGCTTCTCCG	301
345754	coding	1	635	TCCAGCATCTGCTGCTTCTC	302
345755	coding	1	636	CTCCAGCATCTGCTGCTTCT	303
345756	coding	1	638	TGCTCCAGCATCTGCTGCTT	304
345757	coding	1	641	TGCTGCTCCAGCATCTGCTG	305
345758	coding	1	643	GGTGCTGCTCCAGCATCTGC	306
345759	coding	1	645	AAGTGCTGCTCCAGCATCT	307
345760	coding	1	1663	TGGGATTGTTGGTCAGCATG	308
345761	coding	1	1668	ATTCTTGGGATTGTTGGTCA	309
345762	coding	1	1670	ACATTCTTGGGATTGTTGGT	310
345763	coding	1	1671	CACATTCTTGGGATTGTTGG	311
345764	coding	1	1673	TTCACATTCTTGGGATTGTT	312
345765	coding	1	1675	AGTTCACATTCTTGGGATTG	313
345766	coding	1	1677	GAAGTTCACATTCTTGGGAT	314
345767	coding	1	380	AGATTATGAAACACCAAAGT	315
345768	coding	1	382	GGAGATTATGAAACACCAAA	316
345769	coding	1	384	CAGGAGATTATGAAACACCA	317
345770	coding	1	387	TCCCAGGAGATTATGAAACA	318
345771	coding	1	388	CTCCCAGGAGATTATGAAAC	319
345772	coding	1	390	CTCTCCCAGGAGATTATGAA	320
345773	coding	1	392	ATCTCTCCCAGGAGATTATG	321
345774	coding	1	1872	CTTGCCAGCCATGTTTTCTT	322
345775	coding	1	1874	CCCTTGCCAGCCATGTTTTC	323
345776	coding	1	1876	AGCCCTTGCCAGCCATGTTT	324
345777	coding	1	1880	GAGAAGCCCTTGCCAGCCAT	325
345778	coding	1	1882	AGGAGAAGCCCTTGCCAGCC	326
345779	coding	154	1904	GAAGGAGAAGCCCTTGCCAG	327
345780	coding	1	1877	AAGCCCTTGCCAGCCATGTT	328
345781	coding	1	1879	AGAAGCCCTTGCCAGCCATG	329
345782	coding	154	1905	AGAAGGAGAAGCCCTTGCCA	330
345783	coding	154	1907	CCAGAAGGAGAAGCCCTTGC	331
345784	coding	154	1909	ACCCAGAAGGAGAAGCCCTT	332
345785	coding	1	2247	TGCCTCCTCCTTGGGAATGT	333
345786	coding	1	2249	AATGCCTCCTCCTTGGGAAT	334
345787	coding	1	2251	CGAATGCCTCCTCCTTGGGA	335
345788	coding	154	2274	TTCCGAATGCCTCCTCCTTG	336
345789	coding	154	2275	TTTCCGAATGCCTCCTCCTT	337
345790	coding	154	2277	ACTTTCCGAATGCCTCCTCC	338
345791	coding	1	420	TTGCAGGAAGCGGCTATACT	339
345792	coding	1	422	TCTTGCAGGAAGCGGCTATA	340
345793	coding	1	424	ACTCTTGCAGGAAGCGGCTA	341
345794	coding	1	425	GACTCTTGCAGGAAGCGGCT	342
345795	coding	1	427	TCGACTCTTGCAGGAAGCGG	343
345796	coding	1	428	TTCGACTCTTGCAGGAAGCG	344
345797	coding	1	430	CATTTCGACTCTTGCAGGAAG	345
345798	coding	1	2176	TCATTATAGCCCATGATGATT	346
345799	coding	1	2178	GATCTTATAGCCCATGATGA	347

345800	coding	1	2180	ATGATCTTATAGCCCATGAT	348
345801	coding	1	2182	CCATGATCTTATAGCCCATG	349
345802	coding	1	2186	GCATCCATGATCTTATAGCC	350
345803	coding	1	2188	TAGCATCCATGATCTTATAG	351
345804	coding	1	2189	GTAGCATCCATGATCTTATA	352
345805	3'UTR	154	3102	AAAGGCTATGCTGATACAGT	353
345806	3'UTR	154	3104	AGAAAGGCTATGCTGATACA	354
345807	3'UTR	154	3106	ACAGAAAGGCTATGCTGATA	355
345808	3'UTR	154	3107	TACAGAAAGGCTATGCTGAT	356
345809	3'UTR	154	3109	AATACAGAAAGGCTATGCTG	357
345810	3'UTR	154	3110	AAATACAGAAAGGCTATGCT	358
345811	3'UTR	154	3112	TTAAATACAGAAAGGCTATG	359
345812	3'UTR	154	3114	TCTTAAATACAGAAAGGCTA	360
345813	3'UTR	1	2753	GGTCTCAGAGAACACATCCT	361
345814	3'UTR	1	2755	TGGGTCTCAGAGAACACATC	362
345815	3'UTR	1	2757	CATGGGTCTCAGAGAACACA	363
345816	3'UTR	1	2758	TCATGGGTCTCAGAGAACAC	364
345817	3'UTR	1	2761	TGATCATGGGTCTCAGAGAA	365
345818	3'UTR	1	2763	CCTGATCATGGGTCTCAGAG	366
345819	3'UTR	1	2765	CCCCTGATCATGGGTCTCAG	367
345820	coding	154	1912	CAGACCCAGAAGGAGAAGCC	368
345822	coding	154	1916	CAGCCAGACCCAGAAGGAGA	369
345823	coding	154	1917	CCAGCCAGACCCAGAAGGAG	370
345824	coding	154	1919	GTCCAGCCAGACCCAGAAGG	371
345825	coding	154	1920	TGTCCAGCCAGACCCAGAAG	372
345826	coding	154	1922	ATTGTCCAGCCAGACCCAGA	373
345827	coding	154	1924	ATATTGTCCAGCCAGACCCA	374
345828	coding	1	2181	CATGATCTTATAGCCCATGA	375
345829	coding	1	2183	TCCATGATCTTATAGCCCAT	376
345830	coding	1	2185	CATCCATGATCTTATAGCCC	377
345831	coding	1	2187	AGCATCCATGATCTTATAGC	378
345832	coding	1	2191	TGGTAGCATCCATGATCTTA	379
345833	coding	1	2192	TTGGTAGCATCCATGATCTT	380
345834	coding	1	2196	GATATTGGTAGCATCCATGA	381

Example 20

Chimeric phosphorothioate oligonucleotides targeted to
5 mouse STAT3, having 2'-MOE wings and a deoxy gap

In accordance with the present invention, an additional series of oligonucleotides was designed to target different regions of the mouse STAT 3 RNA, using published sequences (GenBank accession number U06922.1, incorporated herein as SEQ ID NO: 82, GenBank accession
10 number U30709.1, incorporated herein as SEQ ID NO: 382). The oligonucleotides are shown in Table 15. "Target site" indicates the first (5'-most) nucleotide number on the particular target sequence to which the oligonucleotide
15 binds. All compounds in Table 15 are chimeric oligonucleotides ("gapmers") 20 nucleotides in length,

composed of a central "gap" region consisting of ten 2'-deoxynucleotides, which is flanked on both sides (5' and 3' directions) by five-nucleotide "wings". The wings are composed of 2'-methoxyethyl (2'-MOE)nucleotides. The internucleoside (backbone) linkages are phosphorothioate (P=S) throughout the oligonucleotide. All cytidine residues are 5-methylcytidines.

Table 15

Chimeric phosphorothioate oligonucleotides targeted to mouse STAT3 having 2'-MOE wings and a deoxy gap

Isis #	Region	Target Seq ID No	Target Site	Sequence	Seq ID No
29800	coding	82	2213	TGGTATGCTGCAGGTCGTT	383
29801	coding	82	2224	CGGCAGGTCAATGGTATTGC	384
29802	coding	82	2230	GGACATCGGCAGGTCAATGG	385
29806	5'UTR	382	11	TTGTACCTCAGCGCGGACGC	386
134027	coding	82	2309	ACTCAAAGTGCCTCCTGCT	95
337354	coding	82	2204	TGCAGGTCGTTGGTGTCACA	268
345821	coding	82	1742	GCCAGACCCAGAAGGAGAAG	90

In a further embodiment, an additional series of oligonucleotides was designed to target mouse STAT 3 RNA, using published sequences (GenBank accession number U06922.1, incorporated herein as SEQ ID NO: 82). The compounds are shown in Table 16. "Target site" indicates the first (5'-most) nucleotide number on the particular sequence to which the compound binds. All compounds in Table 16 are chimeric oligonucleotides, composed of a "gap" region consisting of twelve 2'-deoxynucleotides, which is flanked on both sides (5' and 3' directions) by "wings" consisting of 2'-methoxyethyl (2'-MOE)nucleotides. The number of 2'-MOE nucleotides in the gaps vary from a length of 2 to 5 nucleotides, with the 2'- deoxynucleotides in plain type and the 2'-MOE nucleotides in bold type. The exact structure of each oligonucleotide is designated in Table 16 as the "wing" structure. A designation of 5~10~5, for example, indicates that the first and last 5

nucleotides are 2'-MOE nucleotides and the central 10 nucleotides are 2'-deoxynucleotides. The internucleoside (backbone) linkages are phosphorothioate (P=S) throughout the oligonucleotide. Unmodified cytidine residues which

5

are underscored; all other cytidine residues are 5-methylcytidines.

Table 16

10 Chimeric phosphorothioate oligonucleotides targeted to mouse STAT3, having 2'-MOE wings and a deoxy gap

ISIS #	Region	TARGET SEQ ID NO	TARGET SITE	SEQUENCE	WING STRUCTURE	SEQ ID NO
133003	3' UTR	82	2527	AAAAAGTGCCCAGATTGCCC	5-12-5	99
346030	3' UTR	82	2527	AAAAGTG <u>CCC</u> AGATTGCCC	4-10-5	387
346031	3' UTR	82	2528	AAAAGTG <u>CCC</u> AGATTGCC	4-10-4	388
346032	3' UTR	82	2528	AAAGTG <u>CCC</u> AGATTGCC	3-10-4	389

In a further embodiment of the present invention, an additional series of oligonucleotides was designed to target different regions of the mouse STAT 3 RNA, using published sequence (GenBank accession number U06922.1, incorporated herein as SEQ ID NO: 82). The oligonucleotides are shown in Table 17. "Target site" indicates the first (5'-most) nucleotide number on the particular target sequence to which the oligonucleotide binds. All compounds in table 17 are uniformly composed of 2'-methoxyethyl (2'-MOE)nucleotides. The internucleoside (backbone) linkages are phosphorothioate (P=S) throughout the oligonucleotide, and all cytidine residues are 5-methylcytidines.

20

25

Table 17

Phosphorothioated uniform 2'MOE oligonucleotides targeted
to mouse STAT3

Isis #	Region	Target Seq ID No	Target Site	Sequence	Seq ID No
29803	coding	82	2253	ATCAATGAATCTAAAGTGCG	93
29805	coding	82	2206	GCTGCAGGTCGTTGGTGTCA	390

5

Example 21

Antisense inhibition of human STAT 3 by chimeric
oligonucleotides having 2'-MOE wings and a deoxy gap: dose
response

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In accordance with the present invention, a subset of
the antisense oligonucleotides targeted to human STAT3 was
further investigated in dose-response studies. The
compounds were analyzed for their effect on human STAT 3
mRNA levels in T-24 cells.

15

The transitional cell bladder carcinoma cell line T-24
was obtained from the American Type Culture Collection
(ATCC) (Manassas, VA). T-24 cells were routinely cultured
in complete McCoy's 5A basal media (Gibco/Life
Technologies, Gaithersburg, MD) supplemented with 10% fetal
calf serum (Gibco/Life Technologies, Gaithersburg, MD),
penicillin 100 units per mL, and streptomycin 100
micrograms per mL (Gibco/Life Technologies, Gaithersburg,
MD). Cells were routinely passaged by trypsinization and
dilution when they reached 90% confluence. Cells were
seeded into 96-well plates (Falcon-Primaria #3872) at a
density of 7000 cells/well for use in RT-PCR analysis.

25

Control oligonucleotides used were ISIS 129695
(TTCTACCTCGCGCGATTTAC, SEQ ID NO: 391), ISIS 129694
(GTACAGTTATGCGCGGTAGA SEQ ID NO: 392), ISIS 129690
(TTAGAATACGTCGCGTTATG SEQ ID NO: 393), ISIS 129686
(CGTTATTAACTCCGTTGAA SEQ ID NO: 394), ISIS 116847
(CTGCTAGCCTCTGGATTGA, SEQ ID NO: 395) and ISIS 113529

30

(CTCTTACTGTGCTGTGGACA SEQ ID NO: 396). These are universal scrambled control oligonucleotides.

T-24 cells were treated with 18.75, 37.5, 75, or 150 nM of oligonucleotide mixed with 3 ug/mL LIPOFECTIN per 100 nM oligonucleotide as described by other examples herein. Untreated cells served as controls. Following 16 hours of treatment, RNA was prepared from cells for subsequent real-time PCR analysis.

Human STAT3 mRNA expression levels were quantitated by real-time PCR using primer probe set PPS 199 and gene target quantities were normalized using Ribogreen as described in other examples herein. Data are averages from two experiments are shown in Table 18. A '-' or '+' designation indicates a decrease or increase of STAT 3 mRNA expression, respectively, relative to untreated control cells.

Table 18

Inhibition of human STAT 3 mRNA levels by chimeric phosphorothioate oligonucleotides having 2'-MOE wings and a deoxy gap: dose response

Percent change of STAT3 expression using PPS 199					
		Oligonucleotide Concentration			
Isis #	Seq ID No	18.75 nM	37.5 nM	75 nM	150 nM
106747	58	-37	-48	-71	-84
337247	161	-23	-43	-62	-75
337270	184	-29	-41	-67	-87
337276	190	-40	-61	-76	-81
337284	198	-49	-64	-69	-72
337293	207	-26	-49	-66	-79
337303	217	-44	-61	-69	-72
337332	246	-63	-79	-87	-92
337333	247	-48	-73	-82	-88
337344	258	-27	-47	-63	-77
337348	262	-61	-77	-82	-86
337384	298	-40	-55	-71	-80
129695	391	+5	+2	+8	0
129694	392	+4	-3	-4	-10
129690	393	+2	+7	+6	+8
129686	394	+2	+1	-5	+1
116847	395	+7	+4	+8	+5
113529	396	+1	-1	-11	-26

As shown in Table 18, the compounds tested inhibit human STAT3 mRNA expression in a dose-dependent manner.

The dose-response was repeated in T-24 cells and gene target quantities were measured using a different primer-probe set, called PPS 2033 herein. PPS 2033 comprises probes and primers to human STAT3 were designed to hybridize to a human STAT3 sequence, using published sequence information (incorporated herein as SEQ ID NO: 5 XXX). For PPS 2033 the PCR primers were:
forward primer: GAGGCCCGCCCAACA (SEQ ID NO: 397)
reverse primer: TTCTGCTAATGACGTTATCCAGTTTT (SEQ ID NO: 398)
and the PCR probe was: FAM- CTGCCTAGATCGGC -TAMRA (SEQ ID NO: 399) where FAM is the fluorescent reporter dye and
15 TAMRA is the quencher dye. Gene target quantities obtained by real time RT-PCR are normalized by quantifying total RNA using RiboGreen™ (Molecular Probes, Inc. Eugene, OR).
Control oligonucleotides used were ISIS 129695 (SEQ ID NO: 391), ISIS 129694 (SEQ ID NO: 392), ISIS 129690 (SEQ ID NO: 393), ISIS 129686 (SEQ ID NO: 394), ISIS 116847 (SEQ ID NO: 20 395) and ISIS 113529 (SEQ ID NO: 396).

T-24 cells were treated with 18.75, 37.5, 75, or 150 nM of oligonucleotide mixed with 3 ug/mL LIPOFECTIN per 100 nM oligonucleotide as described by other examples herein.
25 Untreated cells served as controls. Following 16 hours of treatment, RNA was prepared from cells for subsequent real-time PCR analysis.

Human STAT3 mRNA expression levels were quantitated by real-time PCR using primer probe set PPS 2033 and gene
30 target quantities were normalized using Ribogreen as described in other examples herein. Data are averages from two experiments are shown in Table 19. A "--" or "+" designation indicates a decrease or increase of STAT 3 mRNA expression, respectively, relative to untreated control
35 cells.

Table 19

Inhibition of human STAT 3 mRNA levels by chimeric phosphorothioate oligonucleotides having 2'-MOE wings and a deoxy gap: dose response

Percent change of STAT3 expression using PPS 2033					
Isis #	Seq ID No	Oligonucleotide Concentration			
		18.75 nM	37.5 nM	75 nM	150 nM
106747	58	-32	-48	-62	-76
337247	161	+17	-21	-53	-69
337270	184	-16	-27	-67	-87
337276	190	-34	-58	-75	-81
337284	198	-49	-62	-66	-68
337293	207	-26	-49	-67	-79
337303	217	-47	-59	-69	-71
337332	246	-66	-79	-85	-91
337333	247	-46	-70	-82	-90
337344	258	-17	-37	-60	-76
337348	262	-53	-76	-83	-86
337384	298	-41	-59	-69	-80
129695	391	-4	+2	+8	+3
129694	392	+19	-1	+7	+2
129690	393	+4	+10	+8	+11
129686	394	+20	+16	+25	+9
116847	395	+45	+33	+22	-2
113529	396	+1	+12	-11	-24

As shown in Table 19, measurement of target gene quantities using PPS 2033 demonstrates that the compounds tested inhibit human STAT3 mRNA expression in a dose-dependent manner.

An additional dose-response experiment was preformed in A549 cells. A549 cells were treated with 18.75, 37.5, 75, or 150 nM of oligonucleotide mixed with 3 ug/mL LIPOFECTIN per 100 nM oligonucleotide as described by other examples herein. Control oligonucleotides used were ISIS 129686 (SEQ ID NO: 394) and ISIS 129690 (SEQ ID NO: 393). Untreated cells served as controls. Following 16 hours of treatment, RNA was prepared from cells for subsequent real-time PCR analysis.

Human STAT3 mRNA expression levels were quantitated by real-time PCR using primer probe set PPS 199 and gene target quantities were normalized using Ribogreen as described in other examples herein. Data are averages from two experiments are shown in Table 20. A "--" or "+" designation in the dose response results indicates a decrease or increase of STAT 3 mRNA expression, respectively, relative to untreated control cells.

Table 20

Inhibition of human STAT 3 mRNA levels by chimeric phosphorothioate oligonucleotides having 2'-MOE wings and a deoxy gap: dose response

Percent change of STAT3 expression in A549 cells using PPS 199					
Isis #	Seq ID No	Oligonucleotide Concentration			
		18.75 nM	37.5 nM	75 nM	150 nM
106734	45	-2	-16	-56	-73
337332	246	-31	-61	-77	-87
337333	247	-8	-39	-59	-75
337348	262	-26	-43	-55	-77
129686	394	+27	+23	+22	+19
129690	393	+30	+27	+16	+27

As shown in Table 20, the compounds tested inhibit human STAT3 mRNA expression in A549 cells in a dose-dependent manner.

Example 22

Design and screening of duplexed antisense compounds targeting STAT3

In accordance with the present invention, a series of nucleic acid duplexes comprising the antisense compounds of the present invention and their complements can be designed to target STAT3. The nucleobase sequence of the antisense strand of the duplex comprises at least a portion of an oligonucleotide targeted to STAT3 as disclosed herein. The ends of the strands may be modified by the addition of one

or more natural or modified nucleobases to form an overhang. The sense strand of the dsRNA is then designed and synthesized as the complement of the antisense strand and may also contain modifications or additions to either
5 terminus. For example, in one embodiment, both strands of the dsRNA duplex would be complementary over the central nucleobases, each having overhangs at one or both termini.

For example, a duplex comprising an antisense strand having the sequence CGAGAGGCGGACGGGACCG and having a two-
10 nucleobase overhang of deoxythymidine(dT) would have the following structure:

```
          cgagaggcggacgggaccgTT      Antisense Strand
          |||||
    TTgctctccgcctgccctggc      Complement
```

15

In another embodiment, a duplex comprising an antisense strand having the same sequence CGAGAGGCGGACGGGACCG may be prepared with blunt ends (no single stranded overhang) as shown:

```
          cgagaggcggacgggaccg      Antisense Strand
          |||||
    gctctccgcctgccctggc      Complement
```

20

RNA strands of the duplex can be synthesized by
25 methods disclosed herein or purchased from Dharmacon Research Inc., (Lafayette, CO). Once synthesized, the complementary strands are annealed. The single strands are aliquoted and diluted to a concentration of 50 uM. Once diluted, 30 uL of each strand is combined with 15uL of a 5X
30 solution of annealing buffer. The final concentration of said buffer is 100 mM potassium acetate, 30 mM HEPES-KOH pH 7.4, and 2mM magnesium acetate. The final volume is 75 uL. This solution is incubated for 1 minute at 90°C and then centrifuged for 15 seconds. The tube is allowed to sit for
35 1 hour at 37°C at which time the dsRNA duplexes are used in experimentation. The final concentration of the dsRNA duplex is 20 uM. This solution can be stored frozen (-20°C) and freeze-thawed up to 5 times.

Once prepared, the duplexed antisense compounds are
40 evaluated for their ability to modulate STAT3.

When cells reached 80% confluency, they are treated with duplexed antisense compounds of the invention. For cells grown in 96-well plates, wells are washed once with 200 μ L OPTI-MEM-1 reduced-serum medium (Gibco BRL) and then treated with 130 μ L of OPTI-MEM-1 containing 12 μ g/mL LIPOFECTIN (Gibco BRL) and the desired duplex antisense compound at a final concentration of 200 nM (a ratio of 6 μ g/mL LIPOFECTIN per 100 nM duplex antisense compound). After 5 hours of treatment, the medium is replaced with fresh medium. Cells are harvested 16 hours after treatment, at which time RNA is isolated and target reduction measured by RT-PCR.

A series of nucleic acid duplexes comprising the antisense compounds of the present invention and their complements was designed to target STAT3 mRNA, using published sequence (GenBank Accession number L29277, incorporated herein as SEQ ID NO: 1). The nucleobase sequence of the antisense strand of the duplex is 20 nucleotides in length. The sequences of the antisense strand are listed in Table 21. The sense strand of the dsRNA is designed and synthesized as the complement of the antisense strand.

All compounds in Table 21 are oligodeoxynucleotides, 21 nucleotides in length with the two nucleotides on the 3' end being the TT overhang and with phosphodiester internucleoside linkages (backbones) throughout. These sequences are shown to contain thymine (T) but one of skill in the art will appreciate that thymine (T) is generally replaced by uracil (U) in RNA sequences.

Table 21
dsRNAs targeted to human STAT3

ISIS #	REGION	TARGET SITE	TARGET SEQ ID	SEQUENCE	SEQ ID NO
330249	coding	1669	1	ATTCTTGGGATTGTTGGTCTT	400
330247	coding	637	1	CTCCAGCATCTGCTGCTTCTT	401

5

The compounds in Table 21 were tested for their effects on human STAT3 expression in A549 cells. ISIS 330249 targets the same site as the antisense oligonucleotide ISIS 106734 (SEQ ID NO: 45) and ISIS 330247 targets the same site as the antisense oligonucleotide ISIS 113176 (SEQ ID NO: 115); thus, ISIS 106734 and ISIS 113176 were also tested. A549 cells were treated with oligonucleotide mixed with LIPOFECTIN (Invitrogen Corporation, Carlsbad, CA) as described herein. Oligonucleotide concentrations used are indicated in Table 22. The control oligonucleotide used was ISIS 129698 (TTTGATCGAGGTTAGCCGTG, SEQ ID NO: 402). Cells were treated with oligonucleotide for 4 hours and harvested an additional 16 hours later. Untreated cells served as a control.

Human STAT3 mRNA expression levels were quantitated by real-time PCR using primer probe set PPS 199 and gene target quantities were normalized using Ribogreen as described in other examples herein. Data are averages from two experiments are shown in Table 22. A '-' or '+' designation indicates a decrease or increase of STAT 3 mRNA expression, respectively, relative to untreated control cells. Where present, 'N.D.' indicates not determined.

Table 22

Inhibition of STAT 3 mRNA levels by dsRNAs

Percent change in STAT3 mRNA expression in A549 cells by duplex antisense compounds							
Isis #	SEQ ID NO	Oligonucleotide Concentration					
		12.5 nM	25 nM	50 nM	100 nM	200 nM	400 nM
330249	400	-64	-70	-80	-83	-87	-81
106734	45	-5	-5	-40	-56	-67	-77
330247	401	+11	-19	-15	-16	-20	-48
113176	115	+8	+17	+6	0	-22	-34
129698	402	N.D.	N.D.	+41	+42	+1	+22

Example 23

5 Inhibition of tumor growth in LNCaP mouse model

Of prostate carcinoma

The LNCaP murine model of human prostate carcinoma is described in Kiyama et al., *Cancer Res.* 63:3575-3584, 2003, incorporated herein by reference. Briefly, LNCaP human prostatic carcinoma cells were cultured and maintained in RPMI medium (Life Technologies, Inc., Carlsbad, CA) supplemented with 5% heat inactivated fetal calf serum (FCS). About 1×10^6 LNCaP cells were inoculated subcutaneously with 0.1 ml of Matrigel (Becton Dickinson Labware, Franklin Lakes, NJ) in the flank region of 6-8 week old male athymic nude mice (Harlan Sprague Dawley, Inc., Indianapolis, IN) via a 27 gauge needle under methoxyfluorane anesthesia. Mice bearing tumors between 300 and 500 mm³ in volume were castrated via a scrotal approach and randomly assigned to treatment with 10 mg/kg of either ISIS 113176 human antisense or ISIS 129987 human mismatch control STAT 3 oligonucleotide intraperitoneally five times per week for the first week followed by three times per week thereafter. Treatment commenced beginning one day after castration. Tumor volumes and serum prostate specific antigen (PSA) measurements were performed once weekly. Tumor volumes were calculated by the formula $L \times W \times H \times 0.5236$ (Gleave et al., *Cancer Res.* 51:1598-1605, 1992). Blood samples were obtained from tail vein

incisions of mice, and serum PSA levels were determined by an enzymatic immunoassay kit with a lower limit of sensitivity of 0.2 µg/liter (Abbott IMX, Montreal, Quebec, Canada) according to the manufacturer's protocol.

5 ISIS 113176 suppressed the induction of serum PSA levels and tumor growth in the LNCaP xenograft model in castrated nude mice. Similar treatment of mice with the mismatch control oligonucleotide ISIS 129987 had no effect. The observed STAT3 antisense oligonucleotide-mediated
10 effects on PSA and tumor volume were significantly different from mismatch oligonucleotide ISIS 129987 or saline treated controls (student's t-test, $p \leq 0.05$). Treatment effects were demonstrated out to the end of the observation period (10 weeks post-castration). To address
15 the potential target-specific toxicity of this approach, normal mice were treated subcutaneously with an optimized murine STAT3 antisense oligonucleotide (up to 50 mg/kg three times per week for 2 weeks) and pharmacodynamic and toxicological effects were evaluated in the blood, liver and
20 bone marrow. STAT3 antisense oligonucleotide treatment resulted in 85% liver mRNA reduction and significant inhibition of STAT3 protein in the bone marrow pre-monocytic subpopulation. No overt changes were observed in complete blood counts, liver histology or bone marrow
25 subpopulations in animals treated with STAT3 antisense oligonucleotide. Liver and bone marrow expression of STAT3 was significantly reduced by treatment with STAT3 antisense oligonucleotide. Thus, antisense oligonucleotides to STAT 3 represent a therapeutic opportunity for treatment of
30 prostate cancer.